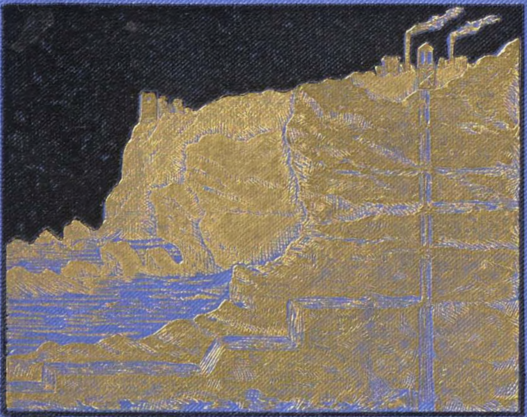
CHIPS FROM THE EARTH'S CRUST

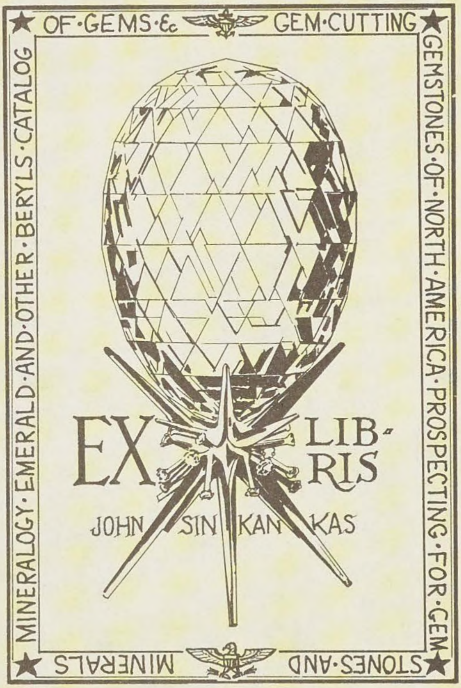
By
JOHN GIBSON



SECTION OF A CORNISH COPPER & TIN MINE

WITH 29 ILLUSTRATIONS

Eric von Rosen 1890



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Eric von Rosen 1890

GOLD-WASHING—AUSTRALIA.

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CHIPS

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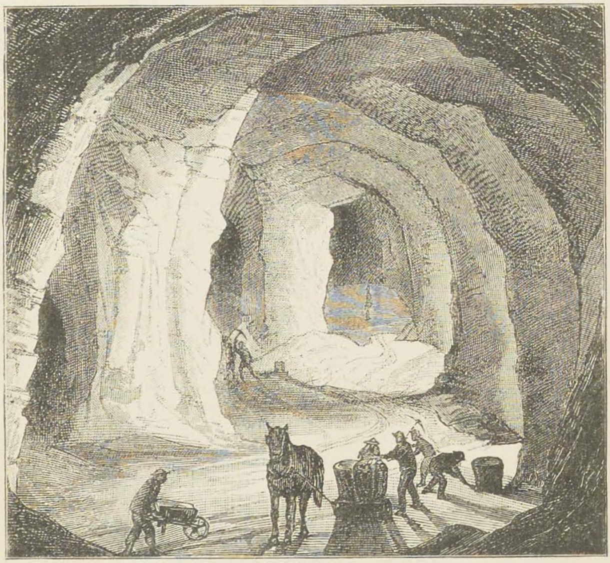

A SALT MINE.

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Thomas Nelson and Sons,

LONDON, EDINBURGH, AND NEW YORK.

CHIPS

FROM THE EARTH'S CRUST;

OR,

Short Studies in Natural Science.

By

JOHN GIBSON,

Natural History Department, Edinburgh Museum of Science and Art.

Author of "Science Gleanings in Many Fields,"
"Monsters of the Sea," etc.

WITH 29 ILLUSTRATIONS.

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Preface.

The Earth's Crust is naturally a subject of very general interest. So closely is Man linked with Mother Earth in his every relation that he cannot in his own interest become too well acquainted with her. Slowly as that knowledge has come in the past, and far as it is yet from having reached perfection, it is not too much to say that more real progress in the knowledge of this our earthly heritage has been made during the present century than in all past ages put together.

It is a healthy sign of a science when its text-books rapidly become antiquated, and this is probably truer of geology than of any other science. It is like the healthy school-boy, who is constantly outgrowing his clothes; and happily for the student of geology, the masters of his science have not been remiss in providing manuals for his ever-growing wants. Text-books, however, are for students, and with most people the time for studying such works

is past. The desire nevertheless to know what is being discovered regarding the Earth is general; and it is in the hope of meeting to some extent this want that the following *papers* have been written.

Few weeks pass without the occurrence of some geological "event" of sufficient general interest to find a place among the news of the day. At the present moment it may be an eruption of Mount Etna; to-morrow it may be a great landslip, an unusually high tide, the discovery of a new gold or diamond field, a fall of meteors, a destructive tornado, or a disquieting earthquake. Such phenomena are ever and anon obtruding themselves on the attention of the reading public; and the plan of the author has been to select such subjects as they have actually arisen, to present the latest facts regarding them, and to discuss them in the light of modern scientific discovery.

The essays in the present volume belong to a series of science articles contributed during recent years to the *Scotsman* newspaper; and the writer has to thank the Editor for his courtesy in granting permission for their republication. The opportunity has been taken to enlarge considerably most of the papers, so as to render them more complete, and wherever possible statistical information has been brought down to the latest date.

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CHIPS FROM THE EARTH'S CRUST.

I.

LANDSLIPS.

HOWEVER much the present configuration of the Earth's surface may be due to the action of those mysterious internal forces which show themselves above ground in the form of earthquakes and volcanoes, it is probable that still more is due to the action of such commonplace agencies as rain, frost, and snow. The surface of every land—unless the few rainless regions of the globe—is being constantly rubbed down, and the eroded material carried off by the rain which falls upon it. The work of destruction is continued by the rain-swollen torrent as it cuts its way to the sea, where it deposits its burden of earth only to join with the rest of the waters in wasting the coast by the impact of its waves. This is what geologists call denudation, and by it valleys and glens have been scooped out and hills and mountains formed.

The amount of solid material thus annually transferred from the surface of the land to the bottom of the sea, chiefly by the agency of rivers, is truly enormous. Thus the Ganges carries every year to the ocean as much solid sediment as would raise a surface of 228 square miles the height of one foot; equivalent, it is calculated, to the removal in the course of 2,300 years of a foot of rock from the entire drainage area of that river. Still greater, however, is the tear and wear of the river Po in the area which it drains, a foot of rock being thus removed by it in the much shorter space of 729 years.

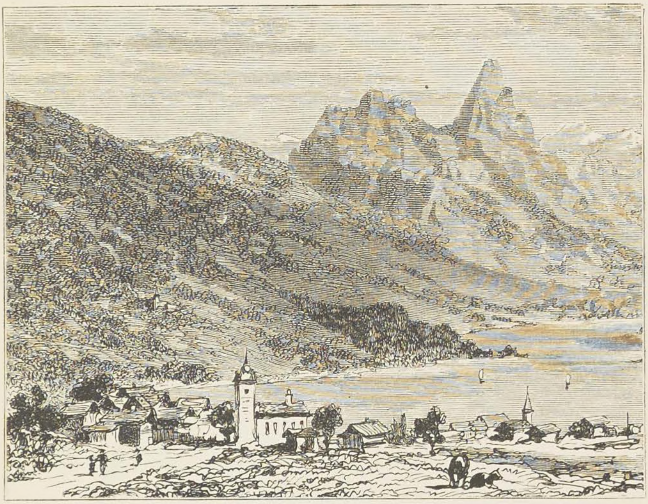
This unceasing transfer of land is for the most part effected without attracting much observation, the waste being so gradual that during the course of a single lifetime things seem to remain much as they were from the beginning. Occasionally, however, the action of those common aqueous agencies is such as to render them fully comparable to the earthquake in the appalling character of their outward manifestation. This is most frequently the case in mountainous regions, especially where the rainfall is excessive. The superabundant moisture percolating through the porous strata of a mountain-side often forms subterranean water-channels, which, as they widen with use, gradually undermine the overlying rocks, until at last the hold of the latter becomes too feeble to resist the force of gravitation, when, suddenly breaking away, they seek a

lower level. The disaster at Naini-Tal in 1880, in which 38 Europeans and about 50 natives lost their lives, was the result of a landslip of this description. Situated on the Himalayan slopes, 6,000 feet above sea-level, this health-resort of Anglo-Indian officials owes its reputation chiefly to its lake—the result, it is supposed, of a former landslip. Such occurrences are said to be not uncommon in that region; one of these, which took place a few years ago, brought down with it an enormous rock, which passed through the wall and deposited itself in a room of the now obliterated Victoria Hotel, from which it could not be removed. The ordinary annual rain-fall at Naini-Tal is said to be ninety inches—about three times that of Great Britain; but its destructive power is greatly increased from the circumstance that almost the whole of it falls during the few months of the rainy season. The catastrophe at Naini-Tal was no doubt hastened by, if not altogether due to, the unusually moist character of the season, no less than eighty inches of rain having fallen during the two months preceding August 17th, 1880; while immediately before the occurrence of the landslip no less than twenty-five inches of rain—equal to the total annual rainfall of many parts of Britain—had fallen in forty hours! It can be readily understood how such a terrific and continuous downpour would not only eat away the surface of the soft Tertiary deposits which flank the

Himalayan slopes, but would loosen, as it sank, the sandy foundations of the superincumbent strata, and thus, unseen and by slow degrees, bring about a catastrophe marked above all others by its swiftness. "A noise," says an eye-witness of this Indian landslip, "a vision of parting earth and moving trees, a rush of matter towards the lake, a roar of water and of falling material, then a deep brown cloud of dust," and all was over.

The annals of mountain regions everywhere abound in instances of landslips, in some cases even more disastrous than that of Naini-Tal. In 1806 the Rossberg—a Swiss mountain lying behind the Righi—was the scene of one of the most appalling of these. Heavy rains acting upon a highly porous under-stratum had so loosened the latter that the entire mountain-side suddenly gave way, and precipitated itself into the valley below, destroying in its progress several villages and hamlets, and burying beneath their ruins no fewer than one thousand of the inhabitants. Although more than seventy years have elapsed since the slide of the Rossberg, its effects are still visible on the mountain-side, and in the piles of huge angular blocks which lie confusedly scattered over the sites of its buried habitations. Two centuries earlier a similar catastrophe overwhelmed the Swiss town of Pleurs, with its entire population of 2,400.

The most disastrous landslip of recent times oc-



VALLEY OF GOLDAU BEFORE THE FALL OF THE ROSSBERG.

VALLEY OF GOLDAU AFTER THE FALL OF THE ROSSBERG.

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curred on September 11th, 1881, at the village of Elm, in the Swiss canton of Glarus. It is a curious fact that the chief catastrophes of this kind in Switzerland have always happened in September. Elm lies at a height of 3,230 feet above the sea, and behind and above it rises the Tschingelberg to a height of 6,000 feet. On the side of the hill above the village slate quarries were worked, the produce of which formed the chief revenue of the commune. The deep excavations thus made into the mountain-side had, it is to be feared, something to do with the bringing about of the catastrophe which occurred. The summer of 1881, which had been exceedingly dry, was followed by heavy rains. These penetrated the cracks and fissures caused by drought and by a succession of earthquakes, and helped to loosen the strata on the steep hill-side. In frequent falls of stones the inhabitants had ominous warning of the coming ruin, and steps were about to be taken to protect themselves. Time, however, was not given for this. At five P.M. on Sunday the 11th the great fir-trees growing high above the quarry were seen to be slowly moving, and to bend "like stalks of corn before the sickle of the reaper." Half an hour later a great mass of rock came thundering down, destroying several buildings on its way. The inhabitants, now thoroughly alive to the imminence of the danger, began to fly with such household goods as they could most

readily carry. In a quarter of an hour, however, another fall occurred, followed immediately by a third—the most frightful of all. "The whole side of the mountain," says one who visited the place immediately after the catastrophe, "gave way, and dashed into the valley below, accompanied by a roar as of a thousand thunders, and enveloping the whole neighbourhood in a thick opaque cloud of dust, producing a darkness deeper than the blackest night." Men and houses were thrown on the opposite side of the valley, smashed against rocks, and buried by this stone avalanche. Of all the people overwhelmed, only one man, aged ninety-two, was taken out alive. Buried under thousands of tons of rock lay the corpses of one hundred and fourteen inhabitants of the valley. The top of the rock fracture was found to be 2,000 feet above the valley; and from this height a mass of rock estimated to weigh about 20,000,000 tons was precipitated. With such force did it descend, that the solid rock was for the most part shivered into the smallest fragments, while the effect upon the air of so great a rush of solid matter was most marvellous. It was remarked by some observers who escaped, that in front of the descending rocks a blast of wind drove down the valley so fierce that it whirled into the air and killed several of the spectators, besides carrying away an iron bridge which weighed twelve tons. Much of the falling rock was carried by the

mighty impetus right across the valley, and, striking the opposite hill, mounted up its sides to a height of 350 feet; while the river which flowed through the valley was blocked up by the *débris,* and its waters formed into a lake.

Earthquake regions are specially liable to landslips, the tremors from beneath producing fissures on the surface which give access to water, and thus set agoing the undermining process. Such movements are of frequent occurrence in Calabria, where great tracts of land have been known to travel four miles down a ravine. Disastrous to life and property as these usually are, cases are on record in which these have been remarkably preserved. Thus, a considerable tract of Calabrian country, with the greater part of a town upon it, slid half a mile from its original site, yet many of its inhabitants were dug out unhurt from the ruins; while another mass, a mile long and a mile and a half broad, moved down a valley to the distance of a mile, so steadily that a thatch cottage and the numerous olive and mulberry trees on its surface appeared none the worse for their removal.

Landslips are by no means unknown in Britain, although, happily, they have seldom been accompanied by loss of life. The land along the greater part of the eastern and southern shores of England is being thus wasted away at an average rate, it is said, of from two to four yards annually, and coast

towns have had to migrate inland in order to avoid entombment by the waves. Thus the entire area on which stood the Yorkshire town of Ravenspur, where Henry IV. landed in 1399, is now fairly out at sea; and so also is the site of the Saxon cathedral church which preceded that of Chichester. This encroachment of the ocean is marked by frequent landslips along the coast, due partly to the action of rains, but still more to the force of the waves. Although usually of inconsiderable dimensions, landslips on an extensive scale have occasionally occurred in this country, as when at Axmouth in Devonshire forty years ago a mass of chalk about a mile in length slipped seawards. In this case the strata had a seaward slope, and were supposed to have been set in motion by previous heavy rains, which, sinking through the porous chalk, reached and rendered exceedingly slippery the clay on which the others rested.

One of the most remarkable instances of land thus sliding into the sea has just been brought under the notice of geographers by the appearance of a new island among the group of the Azores. Reported at first to be the product of a submarine volcano, it has since been found to be merely a slice of another island which had launched itself into the sea to a distance of three hundred metres. This secession from the island of St. George would seem to have been effected with comparatively little

local disturbance, as a number of cattle which were grazing on the land immediately before the occurrence of the landslip were afterwards found feeding on the new island as if nothing particular had happened.

Landslips occasionally occur among the hilly districts of this country—they are not unknown on the slopes of Arthur's Seat—while they are of frequent occurrence on the banks of our rivers. The latter, however, are insignificant in comparison with those which devastate the shores of such great rivers as the Amazon. Bates, in his charming work, the "Naturalist on the Amazons," relates how, in ascending the river, he was on one occasion awakened by a noise resembling the roar of artillery, which he at once attributed to an earthquake. Explosion after explosion followed until dawn of day, when the terrible din was found to result from a series of extensive landslips along the river side. "Large masses of forest," says Bates, "including trees of colossal size, probably two hundred feet in height, were rocking to and fro and falling headlong one after another into the water. After each avalanche, the wave which it caused returned on the crumbling bank with tremendous force, and caused the fall of other masses by undermining."

Landslips, however, may and do occur on level ground, removed alike from mountain, river, and sea; and attention has lately been drawn to a re-

markable example of this kind in Cheshire. The beds of rock-salt which occur in that county form the centre of extensive underground drainage. The fresh water percolating through the upper strata no sooner reaches the rock-salt than it begins to dissolve it, and is thus turned into brine; in which form it is pumped in immense quantities to the surface, and there manufactured into white salt. The wasting and consequent sinking of the saliferous strata produced by this constant influx of fresh and outflow of salt water causes the strata lying above these to subside at an equal rate, so that deep furrows like the beds of rivers mark on the upper surface the position of the underground water-channels. Occasionally enormous masses of earth sink bodily, leaving great cavities; and when these are near rivers they get filled with water, and lakes covering an area of a hundred acres have thus been formed. Houses are said to be frequently destroyed by those landslips, and the damage to property from this cause has become so serious that it has been proposed to appeal to Parliament for assistance.

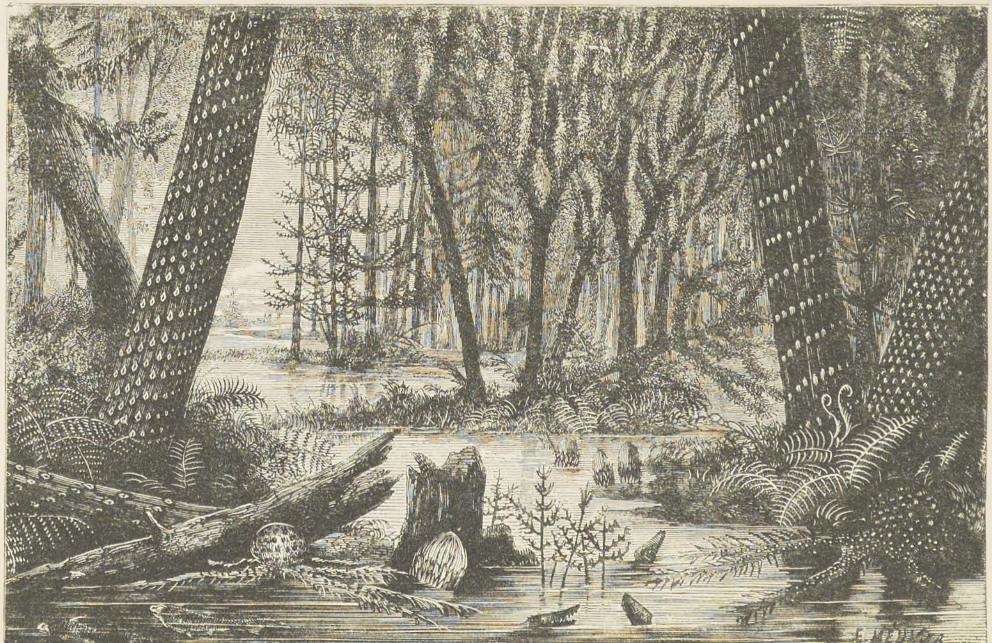
II.

BURIED FORESTS.

Forests are a very ancient feature of the landscape. A few million years ago they were the predominant feature; and that far-back age of forests has left its mark in the present coal-fields of the world. The trees that flourished then were wholly different from those that grow now. Old species have died out, and new ones have arisen many times over since the days of the carboniferous flora. A seam of coal does not naturally suggest a forest, any more than a tin of compressed beef suggests an ox—the mineralized vegetable matter of which it is composed having been compressed beyond all recognition. Exceptional circumstances, such as slow subsidence in tranquil waters, have, however, in some instances favoured the entombment of carboniferous trees as they stood, and have thus preserved to us portions of those truly primeval forests. On the west coast of Arran, near Fallen Rocks, more than a dozen trunks of trees belonging to the lower carboniferous

period were discovered many years ago. These were embedded in ash in the position in which they grew, their roots descending into the shale beneath. That was an age of volcanic activity in Scotland, and the ashes from some active volcano in the neighbourhood had entombed and preserved those Arran trees, just as eighteen hundred years ago Pompeii was buried under the ashes of Vesuvius. Those fossil trunks are not all on the same level; for when the volcanic outburst ceased, a new soil formed above the buried trees, and soon another forest flourished; only, however, to be entombed, like its predecessor, by a fresh outburst of volcanic ashes. A petrified forest of similar age occurs near Elie in Fifeshire.

The best view of a long succession of fossil forests of the age of the coal is, however, to be found in cliffs which for some distance skirt the Bay of Fundy in Nova Scotia. Here the tide, which rises to a height of sixty feet, has laid bare a vast thickness of carboniferous strata, and exposed the erect trunks of fossil trees at no fewer than seventeen different levels. The cliffs thus show in section seventeen ancient forests piled one above another, each forest indicating a period of rest and vegetable growth, followed by a period of tranquil submergence and entombment. The buried trees, or rather what remains of them, seldom exceed six to eight feet in height, although they have been found meas-



IDEAL VIEW OF A FOREST DURING THE COAL PERIOD.

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uring twenty-five feet in length and four feet in diameter. The cliffs are being gradually undermined by the great tidal battery in the Bay of Fundy, so that, according to Lyell, a new crop of fossil trees is brought into view every three or four years. How far these old forests extend inland is not known, but they have been traced "two or three miles from north to south, and more than twice that distance from east to west." In the Sydney coal-field of Cape Breton Mr. Richard Brown has found clear evidence of no fewer than fifty-nine fossil forests ranged one above the other.

Vegetation has probably never since been so luxurious as it was in the days when most of the world's coal was being formed, and through many succeeding periods there is little evidence in the geological record of the existence of vast forests. Doubtless, however, this is to be taken rather as proof of the imperfection of the record than as indicating scantiness of mundane vegetation.

A glimpse of an English forest of Oolitic age is obtained in the island of Portland, Dorsetshire, where, almost immediately above the well-known Portland stone, there occurs what is known to the quarrymen as the *dirt bed.* It is an ancient soil, and on it stand erect the stumps of coniferous and other trees, whose roots penetrate the rock beneath. The climate in those days must have been much warmer than it is now, as some of the Portland plants are

closely allied to forms that now flourish only in the tropics.

One of the most wonderful sights in that wonderland of geology, the Yellowstone National Park of America, is an extensive series of fossil forests, lying one above another, that have been recently described by Mr. W. H. Holmes. These are of Tertiary age—a period during which the whole of that region was, as it still to some extent is, the scene of great volcanic activity. The deposits then formed mainly consist of volcanic products—ashes, scoriæ, and basaltic fragments—which have apparently been redistributed by water, and now form sandstones, breccias, and conglomerates. By a slow but long-continued sinking of the land beneath the water, forest after forest was engulfed in the volcanic *débris*, which seems to have fallen at intervals until a thickness of five thousand feet of sediment had been deposited. There was thus brought about the entombment of a vertical mile of forests. This long period of slow and probably intermittent subsidence was followed by one of gradual elevation until the strata rose to their present height. The Yellowstone River and its tributaries have since cut their channels deeper and deeper into those Tertiary sediments, until in some places they have cut right through to the floor of older rocks on which this great pile of volcanic strata rests. From top to bottom of the lofty cliffs that thus bound the

TRUNKS OF TREES EMBEDDED IN CARBONIFEROUS STRATA.

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Yellowstone Valley the upright trunks of fossil trees are in places to be seen weathered out of the crumbling rocks, and in particular sections rows of them stand out on the ledges like the columns of a ruined temple.

The imposing effect of a succession of such rows of upright trunks extending through a vertical height of two thousand feet of perfectly horizontal strata may well be imagined. Some of the tallest trunks measure from twenty to thirty feet in height; and one, only twelve feet of which is exposed, was found to have a diameter of ten feet. As it is impossible to say how much of the tree the exposed part may have formed, "we are free," says Mr. Holmes, "to imagine that there is buried here a worthy predecessor of the giant *Sequoias* of California." Some of the prostrate trunks measure sixty feet in length and five or six feet in diameter. The roots in many cases are exposed, and are to be seen penetrating, with their minute branchings, what is now solid rock; the bark, too, in some instances four inches thick, is equally well preserved.

These fossil trees have been turned, not into coal. but into a kind of agate. Silica has taken the place of woody fibre; but the ligneous structure is so well preserved in the substituted stone that a transverse section shows all the lines of tree growth from centre to circumference. In the hollows of what have been decayed trunks beautiful crystals of

amethyst and ferruginous quartz were found; and it is an observation worth noting by such admirers of silica in all its forms as Professor Ruskin that "nearly all the beautiful crystals that occur so plentifully in this region have been found in the hollows of silicified trees." Silica in a fluid state appears to have abounded in those volcanic sediments; for, according to Mr. Holmes, not only are all organic remains thoroughly silicified, but all cavities in the loosely bedded rocks, and all fracture lines in the strata, are filled with chalcedony and other forms of quartz. In the cliffs of Shepherd's Hill, Newcastle, in New South Wales, the trunks of fossil trees are similarly exposed; but in these the substituted material is neither coal nor quartz, but red hematite iron ore.

Sir Charles Lyell examined a buried forest on the banks of the Mississippi, one hundred and sixty-five miles above New Orleans. The river here has cut through the alluvial soil, forming a steep cliff on its left bank. At the base of this cliff, he says, "about forty feet above the level of the gulf is a buried forest, with the stools and roots in their natural position, and composed of such trees as now live in the swamps of the delta and alluvial plain, the deciduous cypress being the most conspicuous of them." About one hundred and fifty feet of alluvial sand lies over these buried trees. When they grew on the banks of the Mississippi the land must

have been slowly sinking, and so the river with its sand and mud overwhelmed them. A re-elevation of the ground must then have taken place, which has forced the stream to cut its way, as it is now doing, through the alluvial deposit, disclosing as it descends the history of its past oscillations.

In the desert of Suez, near Cairo, occurs the famous "petrified forest." It consists of thousands of the prostrate trunks of silicified trees, some exceeding sixty feet in length, but most of them broken up into fragments.

A glimpse of a British forest, which flourished just before the advent of the Great Ice Age in Europe, is obtained in the "forest bed" of Cromer on the coast of Norfolk. The stumps of trees still stand erect with their roots fixed in the ancient soil, and mingled with them are the remains of the denizens of this pre-glacial forest. A few of the mammals still inhabit British woods; but with these are associated the mammoth and two other kinds of elephants, two species of rhinoceros, a hippopotamus, a bear, and many other totally extinct species.

Coming to post-glacial and recent times, examples of buried forests are sufficiently abundant. There is scarcely a peat-moss or bog in Great Britain and Ireland which does not overlie the more or less perfect remains of former forests. That the trees grew where they are now found admits of no doubt,

as their stools are still rooted in the soil. They occur not only on the mainland, but in islands such as Lewis, the Orkney and Shetland Islands, and the Faroes, where trees of any sort are now reared with difficulty, and that only in sheltered spots.

These peat-mosses, with their underlying trees, are also seen to pass beneath the level of the sea. While recently excavating for a new tidal basin on the banks of the Thames, the workmen came upon a buried forest, consisting of peat with trees still standing, for the most part, erect, and belonging to such species as the oak, alder, and willow. A similar forest thirty feet below sea level was lately observed and described by Dr. J. E. Taylor on the banks of the Orwell. Scores of instances could be given in which very low tides or heavy storms have disclosed the existence of submerged forests everywhere around the British coasts. Specially noteworthy are the submarine forests at the mouths of the Dee and Mersey. Here at considerable depths beneath the sea level are found beds of peat, with oak, hazel, and pine trees rooted in the underlying boulder clay, showing that when they flourished the land must have extended much farther out into the Irish Sea than it now does. In boring through the recent and post-glacial deposits of the Mersey, the sea is seen to have come and gone more than once since the boulder clay was deposited. The forest whose roots are bedded in this clay is covered

with sand, over which lie clay and silt, showing that the sea had broken over and buried it beneath a marine deposit. A re-elevation of the land would then seem to have taken place; for on the clay are found the remains of a second forest, consisting largely of oak and Scotch fir of great dimensions. This second forest, however, is also buried beneath a deposit of clay and silt, showing that once more the sea had encroached upon the land. The shores of Holland and the Channel Islands, and the north coast of France, afford similar examples of drowned forests. Peat has also been dredged far out both in the English Channel and in the German Ocean.

The existence of submerged forests proves beyond doubt that the sea has encroached upon the land since those trees flourished; and Professor J. Geikie —our highest authority on this subject—regards it as probable that when the oldest of those post-glacial forests flourished, the British Islands were united to one another and to the Continent, and that the North Sea was a great plain through which the Thames, Rhine, and Weser poured their waters into the Arctic Ocean.

The climate, judging from the character and luxuriance of the vegetation, must have been on the whole more genial than it is now. At this time, too, Neolithic man is supposed to have passed into Britain—his "dug-out" canoes and other remains having been found buried in those early

forests. By-and-by the climate became colder; subsidence set in, and Britain became an island. The colder and more humid conditions that then prevailed proved fatal to the forest trees over large areas, but favoured the growth of the mosses that in the end overwhelmed them. Professor Geikie has adduced a mass of evidence in favour of the view that a second period of genial climate, extended land surface, and thriving forests succeeded; followed, however, by another time of humidity and cold, when the land surface again grew less, and many wooded areas were smothered in peat. This period, he maintains, passed away during the Iron age, when the climate again ameliorated, and the sea retreated to its present level. It is our peat mosses, therefore, and not our forests, that would thus seem to be at present in course of burial.

SCENE DURING THE STONE AGE.

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III.

CONCEALED COAL-FIELDS.

In their mode of occurrence, the coal-fields of Great Britain remind one of those patches of snow which linger in the hollows and other sheltered spots of mountain regions long after they have disappeared from more exposed situations. South of the Grampians, Britain, at the close of the Coal period, was for the most part a great "black country," with patches here and there of older land rising out of the surrounding coal-measure strata; while Ireland was little else than one vast coal-field. The close of that period, however, was marked by widespread disturbance of the Earth's crust, resulting in the crumpling up of the horizontal sheet of coal-bearing rocks into huge arches and troughs. The former, as they rose above the water, were planed down by the waves, as well as by rain and other atmospheric agencies, until they were completely denuded of their coal. The troughs, on the other hand, from their more sheltered position, suffered less from de-

nudation; and it is on this account that the existing coal measures are always found in basins. A further great upheaval of strata took place at the close of the next geological epoch, exposing anew the coal-bearing rocks to denuding agencies, and thus still further reducing the extent of British coal deposits. If those destructive forces have thus effected the removal of the major portion of our coal-beds, they have, at the same time, been the means of bringing the remainder within our reach; for had those strata not been thus tilted up and denuded, not a ton of coal would probably ever have been available for human use. Ireland, in this matter, was less fortunate than Britain; and the historian in search of the causes of Irish miseries, must take account of that denudation which ages ago made all but a clean sweep of the broad sheet of coal which once covered most of its surface.

Of existing coal-fields, a considerable area lies buried beneath rocks of later formation, the possibility of working the coal in these being altogether dependent on the thickness of the overlying strata. It has been assumed that mining operations may be carried on to a depth of 4,000 feet; although few of our mines exceed half of that depth, and the deepest known coal-pit is not more than 3,400 feet below the surface. On this assumption, it has been calculated that, while there are about 80,000 million tons of available coal in the visible coal-fields of

Great Britain, there are 56,000 million tons within a depth of 4,000 feet in the concealed coal measures.

The most important of those hidden storehouses of fossil fuel are in connection with the coal-fields of South Staffordshire, and of Yorkshire and Derbyshire; and several successful attempts have been made, chiefly near Doncaster and Birmingham, to reach the coal by piercing through the newer overlying formations. The Bristol and Somerset coal-field has also been traced and worked for several miles beneath later rocks; while in Belgium and the north of France, coal is obtained beneath tertiary and cretaceous strata. So long as the visible portion of a coal-field continues to be productive, the concealed beds, as being more expensive to work, will no doubt be let alone. They form, however, a valuable reserve, to be drawn upon when the more accessible deposits are exhausted.

The occurrence of coal, however, is not limited to a depth of 4,000 feet. A Royal Commission in 1871 estimated the quantities of coal at a greater depth in the exposed coal-fields of Great Britain at 7,320 million tons, and in the concealed coal areas at 41,144 million tons. The Commissioners fixed 4,000 feet as the limit of depth at which men could work efficiently, on the ground that the heat at that depth would be 98° Fahr., or blood heat. At fifty feet below the surface in this country there is a fairly uniform temperature of

50°, and this, so far as actual experiment has gone, is seen to increase by 1° F. for every sixty-four feet of depth. The fact, however, that mines have been worked without inconvenience at depths not greatly under the Commissioners' limit, renders it probable that, with an efficient system of ventilation, coal-pits might be worked below that limit, although the expense of such deep mining might make it more profitable to import coal from countries where it occurred nearer the surface.

The possibility of finding workable seams of coal under the London area has long been a matter of debate among economic geologists, and the question has been recently revived by Professor Judd. The importance of this matter to Londoners will appear from the fact that they annually pay about five million sterling for the carriage of coal from a distance; and it is somewhat remarkable that, with so large a pecuniary interest in the question, more endeavour should not have been made to set the point at rest by means of boring. Geologists are agreed that coal measures extended at one time over the entire metropolitan area; these, however, might afterwards have been either removed by denudation, or buried beneath such a depth of younger strata as to be rendered altogether inaccessible.

The marked resemblance of the strata in the Bristol and Somerset coal-field to those of the great Belgian coal-field, has led geologists to believe in

the probability of the two basins being connected by concealed coal measures extending across the Channel from Calais, and prolonged westward along the Thames valley. This view is further favoured by the fact, already mentioned, that the Somerset and Bristol coal-field has been traced eastward for six miles beneath overlying younger rocks. Coal, if it exists in the London area, would probably, however, occur, as in Belgium, in long narrow basins running from east to west. The most hopeful feature in the search for coal under the metropolis lies in the well-ascertained fact that the later formations which cover the south-east of England thin away towards the east. If coal, therefore, should exist in this area, it is likely to be obtained at workable depths. That it is present and within accessible distance of the surface, has been already proved in localities not very remote from Middlesex. Thus, after boring through the Triassic strata at Burford, in Oxfordshire, the true coal measures were come upon at a depth of 1,184 feet, indicating probably the presence beneath the trias of that locality of a coal-bearing basin. Carboniferous strata have likewise been met with at Harwich at a depth of 1,020 feet, and at Northampton at a depth of 830 feet.

In order to throw light on this question with regard to the district around London, the Sub-Wealden exploration was undertaken several years ago. The boring was made at Battle, in Sussex; but

after reaching a depth of 1,820 feet without taking leave of the younger or secondary rocks, the work was abandoned. The committee, it may be presumed, was unfortunate in its choice of locality; for several borings have since been made in or near London, in which the older or palæozoic rocks have been reached at moderate depths. A year or two ago, an artesian well was sunk for Messrs. Meux and Co., at Tottenham Court Road, in which the older formations were met with at a depth of nearly 1,100 feet, and four other borings have had a like success. These results verify the prediction made by geologists, that a ridge of palæozoic rocks would be found extending at a moderate depth beneath the metropolis; and the evidence now obtained as to their dip proves, says Professor Judd, that the rocks forming this ancient ridge "are bent into a series of east and west folds, and among these folds it is highly possible that coal-measure strata will be found."

The rocks reached in these borings are believed to be Devonian—an older formation than the coal. Their presence, however, no more indicates the absence of coal under the entire metropolitan area than does the presence of Silurian rocks on the Pentland Hills imply the absence of coal measures in Midlothian. Carboniferous strata thousands of feet thick covered the Silurian rocks of the Pentlands until denudation removed them; and the same agency may account for the absence of coal under Tottenham Court Road

without rendering it improbable that coal strata may have been preserved in some fold of the rocks near by. Professor Judd recommends that ten or twelve borings should be made in a line north and south of London at intervals of three or four miles—the average breadth of the Belgian coal basins. If these should yield results similar to those already obtained, it might be safely concluded that denudation had done its work as effectually upon the coal strata of the south-east of England as it did on those of Ireland.

There are many people who would regard the discovery of workable seams of coal in or near London as little less than a calamity. They are appalled by the prospect of disfigured landscape, polluted air, and the quickened growth of a city already grown to alarming proportions. Apart from considerations of economy, Professor Judd has at least one grain of comfort for these people. He believes that coal, if found, will prove to be mainly of that smokeless kind known as anthracite, the general use of which would do much to purify the metropolitan atmosphere.

IV.

FOSSIL FOOTPRINTS.

THE Cingalese Mohammedans are happy in the possession, on Adam's Peak, of what they are taught to regard as a footprint of the first man. Unfortunately, the evidence in favour of the tradition that Adam stood there on one foot till his first offence had been forgiven him does not commend itself to the scientific mind. What were at first supposed to be human footprints on the solid rock have been discovered in various parts of the United States, but a closer examination convinced anthropologists of their artificial origin. They are seen to be cut into the rock, and not indented, as they undoubtedly would have been were they the impressions of naked feet passing over a plastic surface. Specimens of this kind are to be seen in the National Museum at Washington, where they are exhibited as illustrations of aboriginal picture-writing.

Lately, however, in quarrying stone for building purposes at Carson, Nevada, undoubted fossil foot-

prints of a considerable variety of animals were met with, including those of forms allied to the elephant, horse, deer, and wolf, besides the tracks of birds. In addition to these there were impressions which in size and general form suggested the human foot. They appeared to be the tracks of a large biped, and not being those of a bird, it was concluded that they must belong to bi-pedal man. Professor Marsh, than whom no one living has more practical acquaintance with fossil mammalian remains, has had the opportunity of examining casts of these footprints, and he has come to the conclusion that they belong, not to man, but to a gigantic species of extinct sloth, the bones of which have been found in strata of similar age. To account for the tracks being apparently those of a biped, he supposes that their hind feet, which were much the larger, covered the impressions made by the pair in front. That Professor Marsh's view is the correct one has since received powerful confirmation by the discovery that some of the tracks show impressions of the smaller fore feet. The strata at Carson are believed to be of Pliocene age, and undoubted evidence of man's existence at this period is not yet forthcoming either in Europe or America. Although the palæontologist has thus not succeeded yet in obtaining the kind of evidence of the existence of primitive man which satisfied Robinson Crusoe of the presence on his island of at least another human being besides himself, he has learned,

by the evidence of their footprints, and often by that alone, of the existence of numerous extinct animals at almost all periods of the Earth's history.

Nothing seems—and, indeed, few things are—more evanescent than the tracks of birds, dogs, or other animals, which one may see any day on the sands recently left by the receding tide. The next tide inevitably obliterates them. In certain localities, however, there are conditions of shore and tide highly favourable for the preservation of such impressions. Thus the great mud-flats which border on the Bay of Fundy receive an excellent impression of any footstep or even raindrop falling on their smooth and plastic surface. The spring tides rise there to an enormous height, and often great stretches of shore lie dry for a fortnight between spring and neap tides. During this interval the mud with its footprints is baked in the hot sun until it hardens and cracks in all directions. When the tide again rises high enough to cover this surface, it does not blot out the markings; on the contrary, it becomes the chief agent in their preservation, for it covers them over with a thin layer of mud, which every succeeding tide serves to thicken. It is only necessary to take a slab of this hardened mud and split it, in order to find on the lower surface the indented footprint or other markings, and on the upper surface a cast in relief of the same. Lyell and other geologists have seen this going on at the present

day on the shores of the Bay of Fundy, and in the light of this modern instance the occurrence of fossil footprints is by no means surprising.

In the quarry at Carson city already referred to, the sequence of events which led to the preservation of the footprints is plainly recorded in the strata. The upper surface of a sandstone thirty-eight feet in thickness forms the floor of the quarry, and marks the close of a period of strong currents of water depositing sand. "A period of quiescence," says a United States geologist, "ensued, with the deposition of a fine clay or silt. This was drained of water, and became firm enough for animals to walk upon it and leave their tracks. This layer is separated from a second clayey layer by about eighteen inches of sand, marking an overflow and a second period of quiescence and drying up. The tracks are most numerous and distinct upon this layer. Immediately over it we find several inches in thickness of fine clayey sediment penetrated by aquatic plants with the remains of fresh-water shells, indicating the existence of a shallow lake or lagoon for a considerable period." Above this lies a considerable thickness of coarse sandstone.

These various deposits are supposed to have been formed at the mouth of a large river subject to periodic floods, which flowed into a shallow lake probably without outlet. Somewhat similar lakes are found in Nevada at the present day. During

the melting of the snows, the waters of such lakes spread over a very much larger area than in the dry season. With the drying up of the water-courses that feed them, the lakes gradually retreat to their former boundaries, leaving a deposit of mud behind. This readily takes an impression of the footprints of the animals which in the season of drought make their way in crowds to the water edge, and these are sufficiently baked in the sunshine to preserve them until the next overflow of water fills them up with a deposit of mud.

Similar mud flats must have existed ages ago, during the Triassic period, in the valley of the Connecticut River in Massachusetts. These now form sandstones and shale, but as the different strata are laid bare they disclose the footprints of the animals which once traversed their surface; even the raindrops and the sun-cracks have all left their mark. The footprints are very numerous, and give evidence of the presence on those ancient shores of from fifty to sixty different species of animals. Most of them appeared to be the tracks of birds, as each footprint showed three toes, and each toe had the same number of joints as in modern tridactylous birds; and special interest attached to them as being, so far as known, the earliest traces of bird life. Their size, however, was somewhat staggering in view of their ornithic character, as the casts of some of the footprints measured four times that of the ostrich, and

the stride of certain individuals, as measured between one footprint and the next, was about seven feet.

Although these impressions occur in thousands, strange to say, not a bone or other trace of the animals themselves has been found; and Professor Huxley lately pointed to this as one of the most conclusive evidences of the extreme imperfection of the geological record. An abundant fauna, consisting largely of huge vertebrate animals, evidently dwelt in this valley in Triassic times, yet it is to the highly exceptional circumstance of the preservation of their footprints, and to that alone, that we are indebted for a knowledge of their existence. In the past, as in the present, the dead seem for the most part to have obeyed the law of "dust to dust," and the palæontologist may well despair of ever reconstructing, with any approach to completeness, the genealogy of living forms.

That footprints do not always afford conclusive evidence of the kind of creature that made them, is seen in the fact that the impressions in the Connecticut sandstone are now very generally believed to belong, not to birds, nor, indeed, to any biped, but to an extinct order of four-footed reptiles, known as Deinosaurs. The bones of those creatures have been found in contemporaneous and still later strata, and these prove many of them to have been huge bird-like reptiles, which, while possessing a pair of

small front legs, walked more or less habitually on their strongly-developed hind limbs. In the Wealden formation of the south of England similar gigantic three-toed footprints occur; and as these are associated with the remains of iguanodon—a genus of huge deinosaurs—there can be little doubt that the footprints belong to it. This may be said to have been fairly demonstrated by the method sometimes adopted in the detection of crime—namely, by applying the foot to the footprints. Some time ago the burial-place of twenty-three iguanodons was discovered in a mine in Belgium, and the Brussels Museum authorities have been for a long time engaged in disengaging the bones from their stony matrix. They have at length succeeded in mounting and exhibiting the most perfect skeleton of an iguanodon yet seen, standing, as it does, fourteen feet high, and measuring about twenty-four feet in length. That it walked on its hind feet like a bird, and made three-toed impressions like the Wealden footprints, is fairly certain, for a foot of one of the Belgian specimens having been applied to one of those Wealden impressions, the two fitted so exactly as to put it beyond reasonable doubt that those bird-like tracks mark the footsteps of iguanodon.

For many years palæontologists were greatly puzzled over certain footprints found in the new red sandstone of Cheshire. They were those of a

IMPRESSIONS OF RAIN-DROPS, AND OF SO-CALLED BIRD'S FOOT, IN THE MASSACHUSETTS SANDSTONE.

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FOOTPRINTS OF THE CHEIROTHERIUM.

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quadruped whose hind feet were several times larger than the pair in front. Their greatest peculiarity. however, lay in their marked resemblance to the impression of a man's hand, there being five finger-like toes on each, one of which stood out from the others like a thumb. Accordingly, it was named *Cheirotherium*, or "Hand-beast;" and while one naturalist took it for a kangaroo, another thought it more likely to be a crocodile. The controversy was ended by the discovery of the remains of gigantic frog-like creatures, one of which measured three feet in length and two in breath, a variety of circumstances pointing conclusively to the giant batrachians as the "Hand-beasts" of the mysterious footprints.

Tortoises are supposed to have been in existence at least since the Permian age, which succeeded that of the coal; the only proof of this, however, consists in a remarkable series of footprints found on red sandstone slabs in one or two quarries in Dumfriesshire. These have been compared with the footprints made by living species of tortoises as they crawled over soft mud, and the resemblance is sufficiently close to justify the belief that both have been made by the same order of animals. In Corncockle Muir Quarry, where most of the footprints have been found, the tracks indicate that the creatures moved almost invariably from west to east. "The paces," says Sir William Jardine, who has described those relics of ancient life in his "Ichnology

of Annandale," "are generally even and uninterrupted, seldom diverging much aside, showing little stoppage for food, or to scuffle with a neighbour,... and they appear more as the tracks of animals passing at once across some tide-receded estuary, in pursuit of some well-known and favourite grounds which were periodically sought after for business or pleasure." This reminds us somewhat of Darwin's description of the tortoises which he met with in the Galapagos Islands, that travelled inland at regular intervals to certain springs of water to drink. Although the Annandale footprints have been known for half a century, not a bone of those earliest chelonians has yet been found. The footprints evidently belonged to several distinct species, as is seen in the great difference in the size and form of the impressions. The fine collection of footprints made by the late Sir William Jardine is now exhibited in the Museum of Science and Art, Edinburgh.

V.

UNDERGROUND TEMPERATURE.

UNDERGROUND temperature has formed the subject of investigation by a committee of the British Association during the past fifteen years, and a summary of the results of this protracted inquiry was submitted to the Association, at a recent meeting, by Professor Everett. Observations have been made in metallic and coal mines, in wells and wet borings, and in tunnels, not only in Great Britain, but in various parts of the Continent, in Siberia, and in India. The depth available anywhere for actual observation of temperature is, of course, trivial compared with the distance—four thousand miles—from the surface to the centre of the Earth. The deepest mine is not more than half a mile in depth, and the deepest boring is less than three-quarters of a mile, while even the great tunnels which pierce the Alps do so at a maximum depth of only a single mile.

That the ascertainment of the correct temperature

at any given depth in those openings, whether vertical or horizontal, is not the simple matter which at first sight it might appear to be, is made abundantly evident by the report. There are a variety of causes which tend to vitiate underground thermometric readings, and for which due allowance must therefore be made. Thus it was found that the heat generated by the action of the boring tool vitiated the observation unless sufficient time were allowed for its escape. The temperature at the bottom of the great Artesian well at La Chapelle, even some days after the boring had ceased, was found to be fully 7° F. higher than it was after the lapse of four months. Another disturbing cause was found in the presence of such substances as pyrites, owing to the heat generated in them by local chemical action; and in cases where the temperature was found to be abnormally high, it could generally be more or less clearly traced to such chemical action. In the convection of heat—that is, its transference upwards through air or water—there was found a still more prevalent cause of disturbance.

The committee have made due allowance for all such errors of observation, and the results may therefore be regarded as fairly trustworthy. In every case they find that the temperature increases with the depth. This, however, had been satisfactorily ascertained before, the principal object of the present research being to discover the rate of increase. De-

ducing a mean from all the results obtained, they find the average increase of temperature to be 1° F. in every sixty-four feet of depth. This is a slower rate than has generally been supposed, 1° in from fifty to sixty feet having been the rate hitherto generally assumed. This mean has been obtained, however, from extremes showing remarkable divergence, ranging as they do from 1° F. for every one hundred and thirty feet of depth to 1° in every thirty-four feet.

Of metallic mines, those at Przibraum in Bohemia, nineteen hundred feet deep, gave an increase of only 1° in one hundred and twenty-six feet, while the mines at Schemnitz in Hungary gave an average of 1° in seventy-four feet. The shaft of a salt mine at Carrickfergus in Ireland gave the high rate of 1° in forty feet, while the mine at Weardale in Northumberland, with a depth of six hundred and sixty feet, showed the highest rate of all —namely, 1° in thirty-four feet. Of the numerous coal mines examined, three in Lancashire, ranging from a few feet under to about as many over half a mile in depth—the deepest mines in Britain—gave an increase of 1° in fifty-four, seventy-two, and seventy-seven feet respectively. Of borings, that at Sperenberg near Berlin, in rock salt, with a depth of nearly three-quarters of a mile—the deepest in the world—showed an average of 1° in fifty-one and a half feet. Three Artesian

wells in Paris gave 1° in every 56 feet, while a similar well in St. Petersburg had the high rate of 1° in forty-four feet. In striking contrast to the latter is the Bootle well belonging to the Liverpool Water-works, where the lowest rate of increase has been noted—namely, 1° in one hundred and thirty feet. In a well sunk at Yakoutsk in Siberia, to a depth of five hundred and forty feet, the rate of increase was found to be 1° in fifty-two feet; the temperature at that depth was, however, still too low to thaw the permanently frozen ground, and the committee consider it probable that this state of things obtains to a depth of seven hundred feet.

Of tunnels, that of Mont Cenis is exactly a mile below the crest of the mountain through which it passes, and the part of the tunnel with the greatest superincumbent mass upon it was found to be the warmest, the temperature being 85.1°, showing a rate of increase from the surface downward of 1° in seventy-nine feet. The St. Gothard tunnel, which is two miles longer than that of Mont Cenis, is about three hundred feet deeper; and here also the deepest part showed the highest temperature—namely 87 degrees, being an increase of 1° for every eighty-two feet. The greatest divergence is thus seen to exist in the rate at which temperature increases with depth at different localities. A similar difference, however, is observable

in the same vertical shaft. Thus, in the Rosebridge Colliery, near Wigan, Professor Everett points out that in the first five hundred and fifty-eight yards, the temperature rises at the rate of 1° for 57.7 feet; in the next two hundred and fifty-seven yards, at 1° in 48.2 feet; while in the portion between six hundred and five and six hundred and seventy-one yards, it is 1° in 33 feet, although in the deepest part of all the rate again decreases to 1° in 54 feet. This variation in the same shaft may possibly be due to difference in the conductivity of the various rocks passed through; and the committee have added considerably to our knowledge of the degree of resistance offered to the passage of heat by different rock materials. Thus it has been shown that if the resistance of opaque white quartz be represented by 114, then basalt will be represented by 273, and cannel coal by 1538—the latter being one of the worst conductors of heat to be met with in the Earth's crust.

The importance of this inquiry into underground temperature lies in the light which it is supposed to throw on the condition of the Earth's interior. If the temperature rises on an average 1° F. for every sixty-four feet of depth, as it is proved to do in the mile which man has been able to pierce, the boring has only to be carried down another mile in order to reach a temperature of 212° F., and con-

sequently to tap springs of boiling water, which might prove exceedingly convenient when fuel becomes scarce. Indeed, the city of Buda-Pesth is at present largely supplied with warm water from a deep underground source. At a depth of twenty-eight miles the temperature would be high enough to fuse cast iron, and at thirty-four miles to melt that most refractory of all metals, platinum.

The inference from this would naturally be that the Earth consists of a solid crust of insignificant thickness, and of a molten interior; and until lately this theory was generally accepted by geologists. The recent researches of physicists and astronomers have, however, proved it to be no longer tenable. Sir William Thomson, George Darwin, and others have shown that were the Earth other than solid, with a solidity, or at least a rigidity, approaching that of a globe of steel, its behaviour would be very different from what it is under the attraction of the other members of the solar system. "Were the crust," says Sir William Thomson, "of continuous steel, and five hundred kilometres [about three hundred miles] thick, it would yield very much as if it were india-rubber," carrying the waters up and down with it, and thus putting an end to any "sensible tidal rise and fall of water relatively to land."

If the Earth be solid, as physicists seem to say it must, then either the temperature does not go on

increasing with depth, or the material of the nucleus resists liquefaction in a way unknown at the surface. By actual experiment it has been proved that certain substances have their melting-point raised by pressure. Thus, under a pressure of seven hundred and ninety-two atmospheres, spermaceti has its melting-point raised from 51° to 80.2°. Sir William Thomson has also shown that, although the ascertained rate of increase in temperature may hold for the first 100,000 feet of depth, yet that beyond this limit it would begin to diminish, being only 1° in 2,550 feet at a depth of 800,000 feet, while increasingly less at greater depths. It may therefore be that the enormous pressure at great depths serves to maintain the solidity of the Earth's interior, although the heat be such that the slightest lessening of that pressure at any point would cause instant liquefaction. "Such relief," says Dr. A. Geikie in his new textbook of geology, "is doubtless afforded by the corrugation of mountain chains and other terrestrial ridges. And it is in these lines of uprise that volcanoes and other manifestations of subterranean heat actually show themselves."

Many geologists, however, are beginning to doubt the theory that the increase of temperature downwards is a proof at all of approach towards an incandescent nucleus. They point to those wide divergences in the increase of underground tempera-

ture at different localities, and even in the same vertical shaft, and maintain that mere difference in the conductivity of the various rocks is insufficient to explain so great discrepancies. They have consequently sought for other possible sources of high temperature at moderate depths from the surface, and two theories in explanation, one mechanical and the other chemical, have been started. The mechanical theory proceeds on the assumption that through the gradual cooling of the globe the outer portion is contracting upon the central mass, that crumpling and crushing of the so-called crust is the result, and that these violent mechanical movements necessarily result in the development of a large amount of heat. The chemical theory assumes the existence in the interior of the Earth of certain metallic substances in an uncombined state. Should air and water by any means gain access to these, oxidation would ensue with a consequent great local development of heat. This was Davy's chemical theory, which was for a time abandoned owing to the unaccountable absence from volcanic vents of hydrogen, a gas which, according to this theory, must have been evolved in enormous quantities. Later researches, however, have shown that various substances have the power of absorbing many times their own volume of gas, and especially of hydrogen. The probable absorption of hydrogen by the surrounding rock substances has accordingly brought

about the rehabilitation of this theory; and it has gained further consistence from the fact that meteorites have been found which, when heated *in vacuo*, gave off forty-seven times their own volume of hydrogen. But there is a growing belief that the interior of our globe is composed of the same materials as meteorites; and if such be the case, the absence of free hydrogen from volcanic vents need no longer prove a hindrance to the acceptance of the chemical theory of the production of high underground temperatures.

Apart from the scientific interest of this question of underground temperature, it may yet come to have practical importance in connection with the question of the supply of heat for man's use. By greater economy in the use of coal, by the employment of liquid fuel in engines, by the finding and working of concealed coal-fields, the evil day of coal exhaustion may be postponed. But that the world will by-and-by have to get along without coal is a truth that cannot be gainsaid. The days of fossil fuel are numbered; and though the number differs considerably, according to different authorities, some putting it as low as a hundred years, others as high as five hundred, in any case it is but a short time in the life of a nation. It is not a bit too soon, therefore, to be looking about among the various forces of nature for some other source of heat. This Mr. Starkie Gardner has been doing, believing

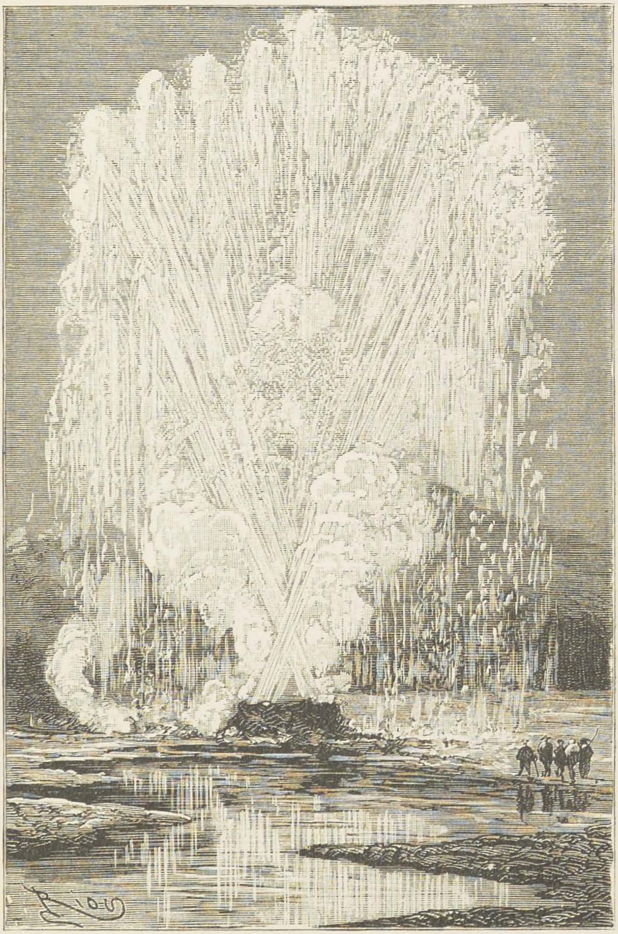
as he does that this matter of fuel may become a burning question even in the lifetime of our children; and in the *Geological Magazine* for September 1884, he ventilates his views regarding the possibility of utilizing underground heat. Physicists are all agreed that, whether solid or liquid, the interior of the globe is intensely hot. The proofs of subterranean heat are numerous and varied. There is no need to descend into the earth to discover this. In volcanic regions it comes to the surface and makes itself seen and felt in rivers of molten rock, that leave the volcanic crater with a temperature of 2,000° F. In former times there is reason to believe that lava welled out on the surface in much greater quantity than it now does. It proceeded not from isolated craters, but from extensive fissures—cracks across continents—and its outpourings now form vast plains of basalt. One of these in the United States covers a larger area than France and Great Britain combined, the cooled lava having an average thickness of 2,000 feet. Another covered an estimated area of 100,000 square miles, extending from the north of Ireland to Iceland and Greenland; and some of the fissures of this great tertiary outburst are now visible in the many basalt dikes that run athwart England and Scotland.

This subterranean heat manifests itself in many other ways. A recent traveller across the Yellow-

stone region says: "There were hot springs and spouting geysers and steaming caldrons of boiling water in every direction. In some parts of the route," he adds, "we seemed to be riding over a mere crust between the air above and a huge boiling vat below." Amidst Icelandic snows the geysers throw up water which a little below the surface is 54° F. above the boiling point. Hot springs are also found in countries far removed from active volcanoes. Thus the hot wells at Bath have a temperature of 120° F., although there are no volcanoes nearer than Hecla and Vesuvius. This high temperature of Bath waters and of many Continental hot springs is possibly due to the great depths from which they rise; for, as has been already stated, the British Association committee has conclusively shown that the deeper one penetrates through the crust of the Earth the hotter it gets. Were the stake great enough—and it will be so when coal is exhausted—there is little doubt that the descent could be made. Mr. Gardner's expectation, however, is that hot water will be found at much more moderate depths, and that its use will greatly lessen the consumption of coal. He points to several instances in which this has been the case. At a depth of about 2,000 feet in mines at Redruth, and in the Comstock silver mines, springs of scalding hot water have been found. Near St. Etienne, where there are very deep coal mines, a vein of hot water was

tapped at a depth of about 1,500 metres, the result being an intermittent geyser which sends its water to a height of above thirty yards. A still more interesting case is that of the Artesian well near Pesth, already referred to, which is, or was recently, being sunk for the purpose of obtaining a supply of hot water for economic purposes. It is already the deepest well of the kind in the world, having reached a depth of 951 metres. According to *Nature*, a temperature of 161° F. is shown by the water at present issuing from the well, and the work is to be prosecuted until water of 178° is obtained. Above 175,000 gallons of warm water stream out daily, rising to a height of thirty-five feet. The work was started partly at the expense of the city of Pesth, in order to obtain an unlimited supply of warm water for the municipal establishments and public baths, and this it is likely to do. It may be mentioned that by means of an ingenious apparatus, the water issuing from this well is used as the motive power in driving the boring drills.

In volcanic countries underground heat is utilized for baths and other purposes. In the geyser region of New Zealand the Maories have placed their settlements where the hot springs afford them facilities for cooking with the least possible trouble to themselves. "Every hut," says a recent visitor to Rotorhua, "has its boiler worked by nature as close to the door as is deemed convenient, and kits or baskets



GEYSER IN THE YELLOWSTONE REGION, UNITED STATES.

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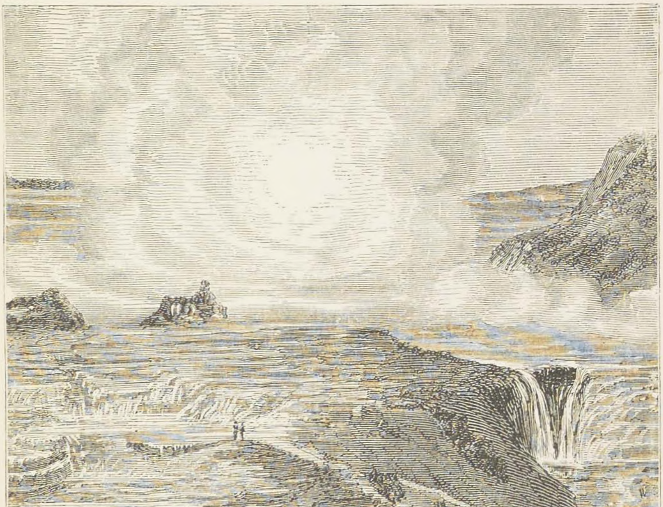
of potatoes, fish, beef, and other edibles are suspended in these pools until ready for table. Over some of the hottest portions of the ground large slabs of stone are placed, on which, covered by moist grass or weeds, bread is baked; on other slabs, not quite so hot, the lazy recline themselves, and, wrapped or covered with a blanket, enjoy Vulcan's heat on the coldest day." According to Mr. Gardner, Vulcan's heat may be enjoyed in non-volcanic countries without the disagreeable adjuncts of earthquakes and lava floods, if only the trouble is taken to bore deep enough for it. He does not recommend sinking a shaft into the great molten sea on which, as he maintains, the comparatively thin crust of the Earth rests; although, could this be done, he does not anticipate that "any uncontrollable eruptions would ensue." The securing of an abundant supply of boiling water, which ought to be had at a reasonable depth, is the most he suggests at present; and that this might be so utilized as to bring about a considerable diminution in the consumption of coal he has no doubt, if a system such as that now in use in many American cities of heating by steam were adopted.

Above a certain vertical limit, varying according to the latitude, and known as the snow-line, perpetual winter reigns. Exceptional circumstances have, however, in a few isolated localities given rise to similar boreal conditions at much lower levels.

Thus, there are certain European caves, outside of which the temperature is considerably above freezing, while within the ice is as permanent as if it were rock crystal. One of these is the famous ice cavern near Dobschau in Hungary, which is said to contain 125,000 cubic metres of frozen water. Its floor is a sheet of glassy ice, where skating can be enjoyed all the year round, while from the roof hang innumerable stalactitic icicles. Some of these have coalesced with the stalagmites of the floor, and have thus become massive translucent pillars, forming corridors and chambers of icy masonry, while the lower portion of the cave contains a succession of picturesque waterfalls in ice. The low temperature which renders possible the persistence of glacial conditions in the cave of Dobschau, Dr. Krenner of Buda-Pesth attributes, among other reasons, to the narrowness and position of the entrance, which prevents all access of sunlight; also to the sloping nature of the floor and the existence of an exit at the bottom, by which the accumulation of unfrozen water is prevented.

Similar caves occur in America; while one—that of Decorah in Iowa—recently described in the *Scientific American* exhibits the paradoxical phenomenon of freezing in summer and thawing in winter. The cave penetrates the side of a hill, and water flows into the lower end of it through a fissure in the rock overhead. Mr. R. M. Lowe, in



HOT SPRING IN NEW ZEALAND.

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a recent paper, has sought to explain the peculiar phenomena of the cave on the theory that the water brings down entangled in it bubbles of air, and that these in their descent are subjected to pressure from which they are relieved on entering the cave. The expansion of cooled, compressed air, however, as is well known, produces cold, and to the continued withdrawal of heat from the surrounding atmosphere by this means Mr. Lowe attributes the production of summer ice in the cave. To explain its disappearance in winter, he supposes that the crevice through which the air and water are supplied gets frozen up near the surface during that season, and that thus an end is put for a time to this natural ice-producing apparatus.

Another example of the presence of frost in unexpected localities occurs in certain of the Colorado silver mines. Those of the Comstock lode are remarkable for their abnormal heat; but there are others in which the miners have, at considerable depths from the surface, come upon great tracts of frozen rock. In one instance this was reached after boring a tunnel about eighty feet into a mountain side. Unable to penetrate it by the ordinary methods, the miners applied fire, and by burning wood each night against the face of the tunnel, they succeeded in thawing sufficient for the mining operations of the following day. As frosts are not supposed now-a-days to penetrate such depths, a

local geologist has had recourse, for lack of better, to the theory that the frozen condition of those rocks is a legacy from the glacial period, abundant traces of which are to be seen in the *moraines* around.

VI.

DIAMOND DIGGINGS.

ALTHOUGH the chemist has at length succeeded in producing the diamond, it is in the last degree improbable that laboratory diamonds will ever compete with the natural stones. Mr. Hannay's successful experiments made evident the enormous difficulties in the way of securing the conditions necessary for their artificial production; and from the great rarity of diamonds in nature, it may be gathered that the requisite conditions for their natural formation have also been of comparatively rare occurrence.

The diamond supply is, and probably always has been, very limited; but a little goes a great way with a material which, when once found, is too valuable to be readily lost sight of, and which is as nearly as possible indestructible. Being merely a peculiar form of carbon, fire will no doubt consume it; but the intensity of heat required to consume it into coke, or to dissipate it altogether, is not likely to be met with accidentally. Diamonds which

passed through the great fire at Hamburg were as brilliant as ever after repolishing.

The precious metals literally perish with the using, but tear and wear have no appreciable effect on the diamond. Consequently, there are stones whose histories are perfectly well known for centuries back, such as the Koh-i-noor of the British crown, which, according to Hindu legend, was worn five thousand years ago by one of their national heroes. Thus, also, it is that India, which for a century past has almost ceased to produce diamonds, is, through its accumulations of past ages, probably the chief diamond-possessing country of the world. A few diamonds have been found in Europe among the alluvial gold deposits of the Ural Mountains, the largest weighing under eight carats; not more have been found in Australia. Borneo has yielded a few, and among these the largest known diamond—belonging to the Rajah of Mattan—which is of the purest water, and weighs three hundred and sixty-seven carats. The world's stock of these gems has, however, been obtained mainly from three localities, each of which has in succession formed the main source. Until a century and a half ago, they almost all came from India, where, in the neighbourhood of Golconda—the name of a fortress where the stones were stored—60,000 persons were employed two centuries ago in diamond digging; and so abundant were diamonds

that Sultan Mahmoud is said to have left in his treasury at his death four hundred pounds weight of them. They occur in a kind of pudding-stone, incrusted so as not to be readily distinguished; the diamond-seekers accordingly break up the stone, and washing it in basins, spread out the resulting gravel to dry, when the gems are recognized as they sparkle in the sun.

The diamondiferous districts of India were gradually getting exhausted, when the discovery of similar deposits in Brazil was made. The stones were found by the natives in searching for gold; but not knowing what they were, they used them as counters in card-playing, until a Brazilian who had been in the East Indies recognized their true nature. A rush of emigrants followed, and the increased production of diamonds which ensued had the effect at the time of reducing their value one-half. The Brazilian diamonds are found in a conglomerate rock, consisting of pebbles of quartz and jasper, cemented together by a ferruginous sand, and having grains of gold disseminated through it. The true matrix of the diamond, however, is believed to be a sandstone known as itacolumite, and sometimes found flexible, the disintegration of which has supplied the conglomerate with its diamonds. During the dry season in Brazil, certain of the rivers are diverted from their channels, while the diamondiferous gravels are removed from their beds and

placed in heaps. The contents of these are afterwards washed in troughs, and the diamonds picked out by the negro slaves, the fortunate finder of one weighing at least seventeen and a half carats being rewarded by receiving his liberty. The largest known Brazilian diamond—found by a negro in 1853—weighed two hundred and fifty-four carats. It has since been cut, and has thus lost fully half of its weight. The stones now found do not weigh on an average more than one carat, and owing to their growing unproductiveness, few of the Brazilian diamond-fields are now worked.

The third diamond-field, and that which now yields the chief supply, is the South African, an interesting account of which was given by Mr. R. W. Murray, a Cape colonist, at a recent meeting of the London Society of Arts. There, as in Brazil, diamonds were being handled by people who had not the remotest idea of their value. The child of a Boer on the banks of the Vaal river was playing with some pretty pebbles which she had picked up, when one of them by its lustre attracted the attention of a passing trader. Having confided to the girl's father his belief that the pebble was a diamond, the trader agreed to halve the profit with him should his surmise prove correct. The Queen's jewellers pronounced it a diamond of twenty-two and a half carats, worth £500; and at this price it was purchased by Sir Philip Woodhouse, at that time

DIAMOND WASHING, BRAZIL.

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governor of Cape Colony. The receipt of half this sum by the parent Boer called to his recollection the fact that he had seen a similar stone in the possession of a native; and seeking him out, he gave him, says Mr. Murray, nearly all he possessed—five hundred sheep, horses, etc.—in exchange for his pebble. It proved to be a diamond of eighty-three carats, and he obtained for it £11,200. This is the stone now in the possession of the Countess of Dudley, and known as the "Star of South Africa."

Such "finds" naturally produced the wildest excitement throughout South Africa, and led to a rush of diamond-seekers, first from the surrounding colonies, and soon from all parts of the world. The early parties had no idea of digging for diamonds; they sought for them on the surface along the ridges of the hills, and succeeded tolerably well. An Australian gold-digger arriving on the scene inaugurated the "cradling" method employed in California and Australia for the separation of the gold in alluvial deposits. The diamondiferous soil, consisting of drift and pebbles of agate, jasper, and carnelian, with here and there a diamond, was dug out, and after thorough washing the gems were readily picked from the gravel. In 1870, within a year after the first rush, there were one thousand cradles at work on the banks of the Vaal. These were known as the *wet* or *river* diggings, but after a time they were abandoned for the more productive

dry diggings. These were too far from the river to render the washing of the diamondiferous material possible, nor was it needed, owing to the light, sandy nature of the soil. The digger had only to pass the stuff through a couple of sieves over a sorting table, when the sorter was able to pick out whatever diamonds it might contain. The first possessors of those dry "claims" dealt only with the loose upper soil, sinking their pits to a depth of only three or four feet. Their successors, however, finding the surface diggings exhausted, tested the rocky stratum beneath—"a kind of loosely-packed rock, blue in colour, and hard to crumble," which the early diggers had regarded as putting a period to their hopes of diamonds deeper down—when they were rewarded by finding that it contained more and finer diamonds than even the best surface deposits. Diamond-mining was accordingly begun, and with it came the need of steam machinery and other expensive plant, necessitating the employment of a large amount of capital and the formation of mining companies. Mines have now been sunk to a depth of nearly four hundred feet, in the course of which reefs not diamond-bearing have had to be cut through, and powerful pumps to be employed to prevent flooding.

Those diamond-bearing areas are circular in shape, and form what are known as "pipes." They are filled with intrusive rocks which have been forced up

DIAMOND DIGGING, SOUTH AFRICA.

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by volcanic agency almost perpendicularly through the surrounding horizontal strata of shale, and through which, as well as through a calcareous tufa usually found on the upper parts of the "pipe," the diamonds are disseminated. Owing to the fact that a large portion of the diamonds consist of fragments, it is generally thought that the "pipe" rock is not the true matrix of the diamonds, but that it has merely been the agent in bringing them to the surface from some lower deposit.

The blue rock containing the diamonds after being brought to the surface is spread out like manure on the ground, where it is broken up by various mechanical means as well as by the disintegrating influence of the weather. It is then taken to the washing-places, where in passing through a series of rotatory sieves it is submitted to the action of water. The residue, after all the dirt has been washed away, falls on a series of sorting tables, each table having a different size of pebbles assigned to it. In front of these stand the searchers, generally the principal men of the mine, picking out the diamonds from the gravelly material before them. According to a recent correspondent of the *Times*, "the visitor may stand by in wonder to see the searcher at the one end pick out his eight or ten big stones per hour, or assist the searcher at the other busily sorting out of the sand innumerable white specks of diamonds. The days' work tumbled into

small snuff-boxes will frequently reach a local value of £1,000."

The richest of the mines is that of Kimberley, which has an area of about seven acres. Its original possessor sold the estate, of which it was but a small part, for £6,000, and it soon yielded to its purchasers from £20,000 to £25,000 per annum in rents. The Kimberley mine contains about four hundred "claims," which in 1877 were worth three-quarters of a million sterling; in August 1881, according to Mr. Murray, they could not be purchased for three and a half million. There is no means of accurately ascertaining the value of the diamond production of South Africa, but the importance of the new industry may be gathered from the fact that the value of the diamonds sent through the post-office in 1879 amounted to £3,685,000. It has been estimated that in the last fifteen years, about £40,000,000 worth of diamonds in the rough have been obtained from Kimberley, and that to possess these when cut and set the sum of £100,000,000 sterling has been paid. Since the finding of the "Star of South Africa" much larger diamonds have turned up, notably one found in 1872, weighing 288½ carats, from which it is believed that a brilliant weighing half as much again as the Koh-i-noor may be cut; and the still larger one found by Mr. Rhodes, recently exhibited to the Queen. Unfortunately, the diamonds of

South Africa are not all of purest water, the majority of them being straw-tinted, and therefore of considerably less value than colourless specimens.

For many years before the discovery of diamonds in South Africa, the world's store of these precious stones was being scarcely added to at all by the produce of diamond mines. These were not yielding more than £50,000 worth annually. The rapidly increasing wealth of the world caused an increased demand for diamonds, and their price was fast rising, when the aspect of things was completely changed by the opening up of the South African diamond-fields. Every year for ten years those fields yielded four million sterling worth of diamonds, with the result that the supply at length exceeded the demand, and the price of these articles of luxury became greatly reduced. The output on this account has of late been somewhat checked, and it is probable that the diamond companies will continue to restrict their output until supply and demand get more equally balanced. It is a mistake, however, to suppose that diamonds will ever be other than an expensive luxury to those wearing them, the enormous expense of cutting so hard a material being of itself sufficient to give them a high value.

The price of diamonds has been still further depreciated by the sale of stolen stones. At every stage in the process of diamond-winning there are opportunities for the dishonest employé picking up

valuable diamonds and secretly conveying them away. He has been known to swallow them, also to put them into the heart of a piece of dough, which he would give to his dog to eat, the animal being afterwards killed by confederates outside, and the stone recovered. The temptation to steal where the property is both so valuable and so small is exceptionally great, and extraordinary efforts have been made by the authorities at Kimberley to cope with the evil. No one can sell or buy a diamond without a license. The possessor of a diamond in the rough must be able to account for it, and every diamond sale is registered. The employés are also subjected to a strict search before leaving the works, and detectives swarm; nevertheless illicit diamond-buying is a flourishing business, it being computed that £500,000 worth of stolen diamonds annually leave the colony.

These diamond discoveries are having an enormous influence in the development of South Africa, which, previous to 1870, was in a decidedly languishing condition. Proof of this is seen in the fact that the import duties for Cape Colony, which in 1869 were under two million sterling, had risen in 1879 to more than seven million. Griqualand West, in which the principal diamond-fields are, now contains several important towns, and a large and enterprising population, rich enough, in the case of Kimberley, to bring their water supply from a distance of four-

teen miles. A trunk railway is about to be constructed to connect the diamond region with Cape Colony, which will have the further effect of developing the other resources of a rich but hitherto inaccessible region. The discovery would seem also to have benefited the natives by finding employment for them at remunerative wages, and by bringing them under civilizing influences. Most of the manual labour at the mines is performed by natives, of whom 640,000 have been registered during the past seven years as servants of claim-holders. These earn twelve shillings per week besides their food; and in the great majority of cases the discipline of steady work has, according to Mr. Murray, transformed those (at first) lean, naked, and stupid natives, into well-dressed, well-fed, and, on the whole, well-behaved workmen, with sufficient intelligence to see to the building of schools and churches for themselves.

VII.

AMBER AND MEERSCHAUM.

MOST of the amber of commerce is obtained from the north-east coast of Prussia, where the quest for it forms an important industry. It is got in a great variety of ways—by fishing, diving, and dredging in the sea, by mining on land, and by collecting on the sea-shore. Eight tons out of a total annual production of about one hundred and thirty tons are thus picked up every year on the coast.

To obtain what is floating about in the water, especially after storms, amber-fishers clothed in leather suits wade out from the shore, equipped with bag-nets attached to long poles. They also visit in boats the precipitous cliffs between Dantzic and Memel, and by means of long poles with iron hooks at their ends they detach loose masses of earth in search of the amber occasionally concealed in them. Excitement is given to the search by the chance of obtaining a prize in the shape of a larger

mass than usual of this mineral, the value of a single big piece of amber being, as in the case of diamonds, much greater than that of a similar weight of smaller fragments. It is rare, however, that amber is found in masses weighing more than a pound, although single pieces weighing several pounds have been known to occur. Not long ago a piece of amber of a dark yellow colour, and clear as glass without being transparent, was fished up opposite Stralsund, which weighed over eight pounds. Another mass weighing eleven pounds was deemed worthy of presentation to the German emperor of the time; while the largest piece of all, now in the Berlin Museum, weighs eighteen pounds.

The larger quantities of Prussian amber appear now to be obtained by dredging. The Kurische Haff, at the entrance to which is the important seaport of Memel, has its channel kept from silting up by constant dredging. This work was formerly done by the Prussian Government, and occasionally the workmen obtained pieces of amber from the dredged-up material. This proof of the presence of amber on the sea-floor led to the offer on the part of a company to undertake the necessary dredging at their own expense, besides paying a rent to Government of twenty-five thalers a day, provided they were allowed to keep all the amber obtained. The offer was accepted, and the bargain appears to have been a profitable one to the company, whose opera-

tions have gradually extended, until now, or at least lately, they employed no fewer than a thousand workmen.

The amber-yielding strata, which, it may be presumed, crop out on the sea-floor, and thus get their amber washed out by the action of storms, extend beneath the soil for some distance inland. To reach this store, pits are sunk to a depth of about one hundred and thirty feet, first through sand and clay, and then through a thick bed of bituminous wood or brown coal. In and below the latter the amber is found, not in veins, nor even regularly distributed like flint nodules in chalk, but scattered about in detached nodular masses, varying in size from a hazel nut to a man's head.

The position of amber among the brown coal strata of lower and middle Tertiary age is suggestive of its vegetable origin. It is no longer doubted that this mineral substance is simply the fossilized resin of certain of the forest trees of a bygone geological period. In tropical regions there are trees now growing which exude resin in enormous quantities, hundreds of tons of it under the name of copal being annually imported into Europe. In chemical composition and in optical properties, amber and copal are almost identical, differences in degree of hardness, of brittleness, and of the amount of heat necessary to soften them being, no doubt, the result of fossilization in the case of amber.

The theory of its vegetable origin also receives remarkable confirmation by the frequent presence in amber of insects and of portions of plants, which had got enclosed while the resin was still in a viscous condition. The insects belong to various orders, including beetles, cockroaches, flies, bees, and wasps; but those which frequent the bark of trees or live in its fissures are the most numerous. They are, for the most part, beautifully preserved, and no fewer than eight hundred insect species—all believed to be extinct forms—have been described from specimens thus embalmed in amber. That the hapless insects endeavoured to drag themselves from the sticky mass may be surmised from the occasional occurrence of a leg or a wing lying apart from the rest of the body, and which had evidently got detached in the creature's struggle to escape. Spiders have also been found in amber, and, in one instance at least, the leg of a toad. Palæo-botanists have also recognized about one hundred and sixty species of plants in the vegetable fragments enclosed in amber, and the veteran Dr. Göppert of Breslau has lately issued a monograph of the coniferous trees in this amber flora. According to this writer the fir tribe, and more especially six species of these, have almost alone contributed the amber, the most important of them being a form closely allied to the common spruce.

No better material than this ancient resin could

have been found for the preservation of plant and animal remains. Beautifully preserved as the insects are, the fragments of embedded plants are equally so. Thus the texture, the microscopic structure, and even the green colouring of the under sides of some of the leaves are still visible. Twenty species of coniferous trees have been determined, and although none of these now exist, they are closely allied to existing species. A curious fact about them, however, is that their living representatives are now found in the most widely separate quarters of the globe. Thus a *sequoia* closely allied to the Californian redwood flourished in this North European amber land, and along with it were forms allied to the incense cedar of Chili, the arbor-vitæ of China, the red cedar of Virginia, the parasol fir of Japan, and two species of a group now confined to the Cape and Madagascar, besides representatives of the Scotch fir, the spruce, and the cypress of Europe.

The richest amber deposits are situated along a strip of coast between Dantzic and Memel, and especially in the province of Samland. It is found in what is known as the " blue earth " of that province—a formation extending sixty miles in length, twelve miles in breadth, and having an average thickness of twelve feet. It has been estimated that every cubic foot of this contains one-twelfth of a pound of amber, which would give a total of

9,600,000,000 lbs. The quantity at present raised is from 200,000 to 300,000 lbs. annually; at which rate there is enough to last for 30,000 years. The amberiferous forest of those early Tertiary times is believed to have extended from Holland, along the German coast, through Siberia and Kamtschatka, on to Behring Strait and North America. That the climate over that northern region was much milder in those days than it is now may be regarded as certain, in view of the luxuriant vegetation thus disclosed, and of the fact that the insect life has a distinctly tropical aspect.

Although the great bulk of the amber of commerce is obtained from north-eastern Prussia, it is found, although much less abundantly, in other parts of the world. Lately, it was thought that an amber mine had been discovered in digging the foundations of a new house in Berlin, several pieces of amber having been unearthed during the work of excavating. These, however, proved too scanty to encourage further mining. It has been occasionally found in gravel pits near London, and has been picked up in Hyde Park, while on the Yorkshire coast it is not infrequently cast ashore after a storm along with pieces of jet. English trawlers also dredge it occasionally from the bottom of the North Sea, and dispose of it along with their fish at Great Grimsby. It is also found in Siberia and Kamtschatka, along the supposed

track of the ancient Tertiary forest. On the Sicilian coast a highly-valued variety, with a bluish tinge and exhibiting a fine play of colour, is found.

Amber appears to have been known and valued as an ornamental stone throughout the historic ages. Homer speaks of "a gold necklace hung with bits of amber;" and the Romans set such store upon it that, according to Pliny, the smallest figure carved in amber cost more, in his time, than a strong healthy slave. The southern shores of the Baltic were then, as now, the chief source of amber, and in the time of Nero an expedition went thither in quest of it.

More than two thousand years ago, Thales of Miletus made the discovery that amber, or *electron*, as the Greeks called it, when rubbed, possessed the property of attracting light bodies; an observation which laid the foundation of the modern science of electricity, and the memory of which is thus perpetuated in the name. This property of becoming powerfully electrical by friction has to be taken into account by those engaged in the manufacture of amber goods, as during the polishing process it becomes highly excited, and is then liable to crack and fly to pieces. To obviate this it is usual for the workmen to take several pieces and to work upon each for a short time in succession. According to Dr. Ure, amber-workers are also liable to be

seized with nervous tremors in their wrists and arms, from the electricity thus developed.

Amber is principally used in the manufacture of pipe-mouthpieces and cigar-holders, also of beads, both large and small; Vienna being the chief seat of the former manufacture, and Dantzic of the latter. The value of raw amber depends on size and quality. Long pieces, suitable for the large pipe-mouthpieces used in Turkey, and numbering four or five to the pound, are worth from £6 to £7, 10s. per pound, while pieces so small as to require one hundred and fifty of them to weigh a pound are not worth more than 3s. per pound. Round pieces, on the other hand, ten of which weigh a pound, and suitable, therefore, for large beads, are worth from 36s. to 38s. per pound. Copal is sometimes substituted for amber, especially in the manufacture of beads. It can readily be detected, however, owing to its greater softness and brittleness. Copal also melts into drops at a flame, while amber merely burns away. Amber becomes flexible when sufficiently heated, and it is said that two pieces may be joined if the edges be smeared with linseed oil and pressed tightly together over a charcoal fire.

Allied to amber, at least in the smoker's mind, is the mineral known as meerschaum. It is not, however, a marine product, although the Germans thus speak of it as "sea foam;"—a fancy which may have arisen from its lightness and whiteness,

and from the fact that pieces washed from their matrix are occasionally found floating in the Black Sea. Although not of organic origin, its mode of occurrence is very similar to that of amber, being found in nodular masses of varying size and shape, scattered through alluvial deposits. It is chiefly found in Asia Minor, where it is obtained by means of pits and galleries cut into the alluvial plains. These mines are sunk to a depth of thirty to forty feet, and from forty to fifty miners, who share in the profits of the concern, work in each of them. When first removed from the pit, meerschaum can be readily cut with a knife. It is first denuded of a thick covering of red oily earth which surrounds it, then it is allowed to dry in the sun for several days, the result of these operations being that it loses nearly two-thirds of its original weight. Before being packed in boxes for export, it is polished with wax. From 8,000 to 10,000 boxes, representing a value of 1,200,000 florins, are annually exported from the district of Eskihi-sher, situated near the most extensive meerschaum deposit in the world. It is also found in Greece, Moravia, and Morocco.

When newly dug it forms a lather like soap, and in Morocco and Algiers it is used as such. Near Madrid a coarse variety occurs, which forms an extremely light but, on the whole, durable building stone. The great bulk of the meerschaum of commerce is used in the manufacture of pipe bowls, for

which its porosity, and consequently its capacity for taking up the oily matter of tobacco, eminently suits it. Vienna, which supplies nearly all the amber mouthpieces used, is likewise the great seat of the meerschaum pipe manufacture, twelve thousand cases of this mineral, each weighing from fifty to sixty pounds, and worth £35 a case, being annually used up in the Austrian capital. After the bowl is turned, the principal step in the process of manufacture is the boiling of the pure meerschaum in wax or spermaceti, and the polishing of it with such substances as bone ash and chalk.

More or less perfect imitations of meerschaum are notoriously common. The best of these, in the sense of being least liable to detection, is that made by the compression of the shavings or dust of meerschaum, several thousand hundredweights of which are thus annually utilized in Vienna. Hardened plaster of Paris treated with paraffine and coloured to the proper tint by gamboge and dragon's blood; also a new composition introduced in France, into which the potato is said to enter largely, are among the many spurious imitations of genuine meerschaum.

VIII.

AGATES AND THE AGATE INDUSTRY.

SCOTLAND, according to Professor Ruskin, is "itself one magnificent mineralogical specimen;" and probably there is no similar area of the Earth's surface from which so many mineral species have been obtained. These include a goodly number of the so-called "precious stones"—as the topaz, the garnet, and such forms of silica as the cairngorm, bloodstone, jasper, and agate. Scotland is famed for its agates, better known as "Scotch pebbles;" which, although small compared with those found elsewhere, are yet unequalled in the variety and beauty of their colours. To the mineralogist, agates have the further attraction of being to some extent enigmas as regards their mode of formation. Professor Ruskin, in a recent paper to the Mineralogical Society, stated that the question of the production and painting of a Scottish pebble had been more or less the occupation of his best wits ever since childhood, yet he had not solved the problem. His

advice, however, to the rising generation of mineralogists, that "a quick eye, a candid mind, and an earnest heart were all the microscopes and laboratories they needed," raises the suspicion that the professor's methods were defective. In the days when quick eyes were unaided by microscopes and laboratories, rock-crystal was regarded as petrified ice, and agates were esteemed as an infallible specific in many diseases.

Agates are found in trap and other ancient volcanic rocks, where they lie like almonds in a cake. Their presence there is explained in the following manner:—When those palæozoic traps were molten lavas, they were more or less saturated with steam, as many modern lavas are; and the expansion of this imprisoned vapour in the still plastic rock produced cavities throughout its mass, just as the gas generated by fermentation in bread gives rise to a cellular structure in the previously solid dough. Subsequently water, holding more or less carbonic acid in solution, filtered through the cellular trap rock, and gradually dissolved out its silica; and this siliceous liquid entering the cavities, there deposited its mineral matter until these got filled up. Thus it is believed agates have come to be in those ancient trap rocks. The main difficulty lies in understanding the mode of entrance of the silica into the cavity, so as to produce the concentric layers so characteristic of the agate. These in some cases are

so fine that one hundred of them may be counted in the space of a quarter of an inch.

Dr. Reusch has shown how the agate structure may be strikingly reproduced artificially. He took an irregularly-shaped cavity, and introduced into it a thin cream of plaster of Paris, which, after shaking round, he poured out, thus leaving a thin coating of the material lining the interior. This was repeated with different coloured creams of plaster, until the entire cavity was filled up; and on cutting through the nodule thus formed, the concentric layers of different coloured plasters exactly reproduced the appearance of a banded agate. It is difficult, however, to see how such a process of rinsing the cavity with a solution of silica could have been effected in nature.

Until lately, the favourite theory was, that the silica made its way into the hollow by a special opening termed the "point of infiltration;"—the only argument, apparently, in favour of this view being the fact that many agates when cut show a channel somewhat resembling the neck of a bottle, through which the agate-forming material was supposed to have flowed. On this theory, however, it is impossible to understand how the layers of silica should have been deposited of equal thickness all over the interior of the cavity, as in most cases they are. The more generally accepted theory now is, that the solution of silica passed everywhere through the

porous walls of the cavity by what is known as *osmosis*, and was thus deposited equally over its interior. A residual water gathered in the cavity, and as the latter got filled up with siliceous deposit, this water was gradually forced out through the so-called "point of infiltration;" which thus formed a means, not of entrance, but of exit. "The point of infiltration," says Dr. Heddle, in a recent number of *Nature*, "instead of being at once filled up, as would result from the inflow of coagulable silica, is in reality the last point filled up, being truly the point of escape; indeed, it frequently is not altogether filled up, remaining an open tube."

The colours in different agate bands are due to the presence of oxides of iron and manganese, and partly also, it is supposed, to differences in rate of deposition; but why silica should deposit itself in one layer as chalcedony, and in another as jasper, while in a third it is amethystine quartz, are points that still await explanation.

Scottish pebbles are found chiefly at Kinnoul Hill, near Perth; on the shore near Montrose; at Dunglass; and at Burn Anne, near Galston, Ayrshire: but whether they occur on the shore or in river gravels, they have been all previously washed out of trap rocks. The pebbles cut by Edinburgh lapidaries are used in the manufacture of Scottish jewellery.

The chief seat of the agate industry of the world,

however, is at Oberstein, in Rhenish Bavaria, where it has been carried on for centuries. It arose there naturally enough, owing to the presence in the volcanic rocks of the neighbourhood of abundance of fine agates; but it has continued and extended long after those rocks have ceased to yield, or at least to be mined for, the raw material of the industry. The agate quarries of Oberstein were abandoned owing to the discovery, fully half a century ago, of a rich supply of those stones in the river gravels of Uruguay. Some German workers in agate, who had emigrated to that region, noticed the court-yard of a farm-house paved with pebbles that reminded them of the agates of their native Oberstein. Specimens were accordingly sent home and cut, and the surmise proved correct. Since that time there has been a regular export of agate nodules from Uruguay to Oberstein, where they have long formed the staple material used in the agate-mills. Many of them are of large size, although in this respect few can compare with the agate found at Oberstein in 1844, which weighed one hundred and ten pounds. By their first discoverers these New World agates were found lying loosely in the soil. The trouble of collection was therefore slight; and as they were for the most part taken as ballast to Europe, their carriage cost but little. Now, however, they are scarce, the right of searching for them has to be paid for, the government has put a tax on their ex-

port, and they are no longer carried as ballast. These "Brazilian agates," as they are called, when brought to Germany are arranged in lots and sold by auction, stones of ordinary quality bringing, it is said, not more usually than fifteen shillings per hundredweight. Before the sale the different lots have been carefully examined by the agate-workers, little bits being chipped off, and their capacity for taking artificial colours tested. "German agates" are thus for the most part South American stones cut and polished at Oberstein.

The extent of the industry has greatly increased with this accession of fresh material, and a few years ago there were no fewer than one hundred and fifty-three agate-mills, working seven hundred and twenty-four grindstones, and giving employment altogether to about three thousand persons. Cheapness of labour and a plentiful supply of water-power have had much to do with the continuance of this industry at Oberstein. The labour is both ill-paid and severe. The agate-worker, says Professor Rudler, who some years ago visited the mines and mills, "lies upon a low wooden grinding-stool, specially constructed to fit to the chest and abdomen, leaving the limbs free; the hands are engaged in holding and grinding the agate, whilst the feet are firmly pressed against short stakes or blocks of wood screwed into the floor—the reaction enabling the grinder to press the agate with much force

against the moving millstone." Unnatural as this position is, experience has shown it to be the one which gives the workman the greatest command over his work; and that it is not detrimental to the health of the operator would appear from the generally healthy appearance of the men. The friction thus produced causes the agate to glow with a beautiful phosphorescent light, and red carnelians under this treatment look, it is said, as if they were red-hot. The millstones are of red sandstone, measure five feet in diameter, and generally make three revolutions per second. When in any way defective, or when used too soon after leaving the quarry, these stones have been known to fly in pieces with great violence while rotating, and several fatal accidents have arisen from this cause. The finer agates are sliced by means of steel wheels and diamond or emery powder, but the coarser stones are simply chipped into shape and ground. Afterwards they are polished on rotating cylinders of wood or lead covered with moistened tripoli.

The ingenuity of the agate-worker is not confined merely to cutting, carving, and polishing his material into all manner of shapes. He has also succeeded in varying its colour by artificial means. The layers composing an agate differ considerably in porosity; those that are transparent, for example, being less porous than opaque layers. Some, indeed, seem to be altogether impervious at ordinary

temperature and pressure ; and agate-workers both at Oberstein and in India have availed themselves of this peculiarity in applying their staining processes.

A suitable agate, after being thoroughly dried, is immersed in a mixture of honey and water or in olive oil, and is kept thus for at least three days, exposed to a moderate heat. It is then washed, dried, and put into a vessel containing enough of sulphuric acid to cover it. The vessel is thereafter exposed to a gentle heat for a varying number of hours, when the porous layers are found to have become much darker in colour. The reason of this is, that these layers, having become saturated with the syrup or oil, are acted upon by the sulphuric acid, which decomposes the sugary or oily constituent, and forms in its place a deposit of carbon. It is in this way that banded agate is converted into the onyx, with its black and white layers, used in the production of cameos and intaglios. The Italian cameo-cutters appear to have been acquainted with a process for staining agates from very early times ; but although they visited annually the mines at Oberstein, in order to buy the finest onyxes, their staining process remained a secret till 1819. During that year, it is said, a German agate-worker became acquainted in Paris with a Roman stone-engraver, and that, getting into difficulties, they found themselves in prison together. Here, naturally, they talked much of their agate-cutting,

and the talkative Italian disclosed the secret of onyx-staining—a process which found its way soon after to Oberstein.

Exposure to strong sunlight was long ago found to give a reddish tint to gray-coloured agates, and this suggested the burning of such stones so as to convert them into carnelians. At Oberstein, likely stones for this purpose are first dried thoroughly, then saturated in sulphuric acid, and afterwards exposed in an earthenware crucible to a red heat. They are allowed to cool slowly, and are then seen to be of a bright red colour. In India it has long been and still is the practice to convert yellowish chalcedony into red carnelians by exposure to solar heat alone, the change of colour being brought about by the expulsion of the water from the hydrated peroxide of iron, the colouring matter normally present in the stone. The stones brought from Uruguay and Brazil are much more porous than the true Oberstein agates, and so lend themselves most readily to this art of artificial colouring.

Not content with imitating the rarer natural varieties of agate, such as onyx, carnelian, and the curious dendritic markings in mocha-stones, German manufacturers have taken to staining agates blue and all sorts of colours unknown in the natural stones. Aniline dyes, as unnatural as they are fugitive, have also been lately used for agate-staining.

It is possible that the stones themselves may yet

be artificially produced; indeed, according to King ("Natural History of Gems"), a Florentine anatomist long ago accomplished the feat, although, unfortunately, the secret died with him. He is said to have petrified human viscera into real agates. "In the Hospital of S. Spirito may be inspected still by the incredulous," says King, "a table-top made up of hearts, lungs, livers, etc., thus agatized into one large slab—meet board for a banquet of vampires!" Organic remains in agates are not unknown, for Bowerbank states that in the moss-agates of Oberstein he has found microscopic organisms; and Dr. Heddle that he has found undoubted organic remains of considerable size in agates from Ayrshire and other localities.

IX.

FLINTS AND THE FLINT INDUSTRY.

WHAT iron has been to man during the Historic period flint was during the Stone age. Hard, yet easily broken, and with a fracture which readily lent itself to the production of a cutting edge, flint was in great request throughout prehistoric times as the raw material for implements and weapons, the larger pieces being formed into axes, the smaller into knives, saws, awls, arrow-heads, and lance-heads.

Flint is not universally distributed, being found chiefly in the form of nodules, disposed in layers through what is known as the upper chalk formation. It consists of pure silex, and has been secreted from the ocean water, generally around some organic substance, as a bit of sponge. Hence that or some other fossil organism is usually, though not invariably, found in the centre of the mass of flint. When first quarried flints are exceedingly brittle, and are usually humid when broken; but after a

short exposure to the air they acquire their characteristic toughness.

The more homogeneous the flint, the better was it for the purpose to which it was put in prehistoric times; and manufactories of stone implements and weapons flourished in localities noted for the abundance and good quality of their flint, just as Sheffield and Birmingham, situated in the midst of the iron-producing district of England, have, for a like reason, become famous for their hardware. One such prehistoric manufactory has been discovered at Pressigny, in France, where there is an abundance of good flint of a peculiar honey colour; and there is proof that the stone cutlery of Pressigny was known throughout prehistoric France and Belgium.

There is abundance of flint in the south of England, where, in some parts, it is used as a building stone and for road metal. No better flint exists in England than is found at Brandon in Suffolk, its comparative freedom from fossils rendering it singularly homogeneous. Nor have its merits been overlooked, for from the earliest times down to the present day it has been utilized in the manufacture of flint implements.

Although there are many circumstances which render it probable that man lived in Britain before the advent of the great Ice age, direct evidence of the fact is wanting. That he did occupy it, how-

ever, before the glacial epoch had passed away—namely, during one of the interglacial periods—is proved by Mr. Skertchly's discovery of palæolithic flint implements at Brandon, in a brick earth which clearly underlies, and is therefore older than, the chalky boulder clay of glacial origin. The earliest certain evidence of man's presence in Britain is thus associated with the manufacture of stone implements at Brandon; and as the last glacial epoch is believed, on astronomical grounds, to have occurred rather more than two hundred thousand years ago, the great antiquity of this Brandon industry is undeniable. Extremely rude are these early examples of the flint manufacture, the people who made and used them being cave-dwellers, ignorant of agriculture and of the potter's and weaver's arts, without domesticated animals, and living on the produce of the chase, while as yet the reindeer, bison, mammoth, woolly rhinoceros, and cave-bear roamed in British forests.

With the close of the Ice age the Old Stone folk seem to have passed away, and the neolithic men who appeared in Britain long after in their stead were of an altogether higher type of civilization. They brought with them the dog, horse, sheep, and other domesticated animals; they grew crops and manufactured pottery. Their implements and weapons were still of stone, but these, as Sir John Lubbock remarks, "were more skilfully made, more varied in form, and often polished."

THE CHASE DURING THE STONE AGE.

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In the Neolithic or Newer Stone period there is ample evidence that Brandon was a great emporium of the flint industry. About three miles from it are a series of circular depressions, about one hundred and fifty in number, and from thirty to sixty feet in diameter. They are locally known as Grime's Graves, and their exploration by Canon Greenwell many years ago proved them to be neolithic flint workings. These old shafts were sunk to a depth of about thirty feet, whence galleries were driven in various directions on the level of the bed of flint to a distance not exceeding their depth. Shallow as were those shafts, and short the galleries as compared with those of modern mines, the task of excavating them must nevertheless have been herculean, in view of the fact that their only tools were stone celts and picks made from the antlers of red deer. Part of one of the galleries explored by Canon Greenwell had evidently fallen in so as to block up the passage. On the removal of this impediment, two of those picks were found lying as they had been left by the workmen. "It was a most impressive sight, and one never to be forgotten," says the canon, "to look, after a lapse it may be of three thousand years, upon a piece of work unfinished, with the tools of the workmen still lying where they had been placed so many centuries before." The picks still retained upon their chalky incrustation the impressions of

the workmen's fingers. The ground in the vicinity of those ancient mines is still strewn with flakes and cores—the *débris* from the manufacture of the celts and arrow-heads of neolithic times. That the Brandon artisans attained great skill in the fashioning of those tools is seen in the flint arrow-heads that have been found, which show that triumph of neolithic skill, the ripple chipping of the surface, an art which is totally lost at the present day. The instrument at first used for the work was merely a stone hammer, of oval shape, held in the hand; later on, this hammer-head was drilled through and a handle inserted. It is probable, indeed, that the highest development of the art of fashioning flint implements was attained after the introduction of metal had supplied the stone-knappers with better tools. The metals, which may thus have enabled them to produce the finest examples of stone implements, gradually supplanted stone as the raw material of the manufacture, and with this change the Neolithic or Newer Stone period came to an end.

With the triumph of metallic over stone implements the flint industry must have declined almost to extinction. That it never died out altogether at Brandon is the opinion of Mr. Skertchly of the Geological Survey of England, who has studied the question very thoroughly on the spot. This belief is founded on a variety of considerations. The use of

FLINT IMPLEMENTS.

1, 2, 3, 4. Flint Arrow Heads. 5, 6. Flint Axes. 7. Flint Knife. 8. Flint Scraper.

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metal tools in preparing the finer flint implements would, he considers, lead to the discovery of the fire-producing value of flint, and thus a fresh impetus would be given to the flint trade by the growing demand for strike-a-lights. Before the discovery of lucifer matches, flint and steel, and, still earlier, flint and pyrites, were in general use as fire-producing agents; and Dr. Evans estimates that they have been thus used for two thousand years in Britain, many of the so-called "scrapers" being, in the opinion of some archæologists, merely old strike-a-lights. There is evidence that these ancient fire-producers were manufactured at Brandon; and there they are still made, considerable numbers in the form of circular discs, two inches in diameter, being exported at the present day to Brazil and the East. They are still, according to Dr. Evans, in constant use in France and Germany in conjunction with German tinder, by tobacco smokers, and we have frequently seen them used for this purpose in the rural districts of Scotland.

The introduction of firearms gave another notable impulse to the flint industry in the demand that arose for gun-flints. Flint-lock muskets were introduced into the English army in 1686, and they continued in use till 1835, when they were superseded by percussion caps. Throughout this period the manufacture of gun-flints flourished at Brandon; and although chemical science, with its lucifer

matches and percussion caps, has rendered the use of flint now-a-days somewhat of an anachronism, yet it has not extinguished the ancient industry of Brandon. As a means of firing a musket or pistol the flint is far from reaching the certainty of the modern percussion cap. Mr. Skertchly, experimenting on this point, found that out of one hundred shots with a flint-lock pistol provided with a new flint, the pistol fired thirty-six times, flashed twenty-five times, and missed thirty-nine times. There is still a brisk demand for gun-flints in Birmingham and Sheffield, whose merchants export them to Brazil, the African coast, and some parts of North America. The gun-flint trade, however, according to Mr. Skertchly, is steadily dying out, not so much from a falling off in the demand, but from a lack of hands to carry it on, and large orders for hundreds of thousands of gun-flints have on this account been, it is said, recently declined. In 1878 there were twenty-six men and boys employed at Brandon in the work, being, it seems, ten fewer than in 1868.

The method now followed in the manufacture of flints at Brandon has many points of industrial and antiquarian interest; and the following account is condensed from that given by Mr. Skertchly, which is by far the most complete that has yet appeared. The blocks of flint, varying in weight from a quarter of a hundredweight to two hundred-

weights, are brought from the pits, and in summer placed outside to dry. In winter, however, they are stacked round the fire-place. Taking up one of these, the workman taps it gently with his hammer, the tap telling him whether it is sound or not. If it is full of cracks, the tapping causes it to fly in pieces with a jarring noise. If the hammer rings, the flint is sound. He then proceeds to *quarter* it; that is, to break it into pieces of convenient size for working. This is done by letting a pretty heavy hammer fall through a space of about a foot, the blow being given from the elbow, and very little power being put into it. Pieces of convenient size being thus obtained, the next operation, and the one requiring the greatest skill and nicety of judgment, is that of *flaking*. To obtain proper flakes, "the stone must be struck at the proper angle, in the exact spot, with a certain force, and by a given portion of the hammer face; and all but the first of these elements vary with every flake." It is not surprising, therefore, that but few of the workers in flint attain proficiency in the art, while many leave this branch of it alone altogether. Gun-flints are of many different kinds, according to the nature of the weapon for which they are intended, whether muskets, carbines, horse-pistols, etc.; and the flaker keeps in view the nature of the orders he has on hand as he strikes off his flakes. With five tubs surround-

ing him to receive the results of his work, he classifies them as he proceeds. So fast does a good flaker work, that by the time a flake falls into the tub a fresh one is struck off: in this way an average workman will make from seven thousand to eight thousand flakes in a day, and a good one ten thousand. A single workman has thus been known to make sixty-three thousand in a week. The final process is that of *knapping*, by which the flakes are formed into gun-flints. A good flake will make four, and a very good one five, flints; but it would be impossible in our space to describe the complicated process of cutting the flake, and of trimming the resulting chips into gun-flints. So rapid, however, is the process, that a skilful workman will make eleven well-finished specimens in a minute. Each knapper has a style of his own, which enables him by feeling them to distinguish flints of his own manufacture. In a day of twelve hours a good workman will knap from three thousand to four thousand flints. As each flint is finished it is dropped into one of a number of tins, according to a certain recognized classification.

It is impossible to estimate with anything like accuracy the amount of time that may have elapsed since neolithic man excavated Grime's Graves, although Mr. Skertchly, in a lecture delivered recently at the London Institution, stated that it could not be less than four thousand years; many

good reasons, however, have been given for believing that the Brandon gun-flint manufacture is a direct descendant of neolithic times. The modern flint pits, both in outside appearance and in subterranean plan, bear considerable resemblance to the ancient excavations. The pick used by neolithic man in digging into the chalk consisted, as already stated, of the antler of the red-deer, from which all the tines, excepting the one nearest the root or *burr*, had been broken off. The pick used by the modern digger for flint at Brandon is unlike all other picks made, but is a fairly exact copy in wood and iron of the antler picks found buried in Grime's Graves. The most interesting of the tools used by the Brandon flint-knappers is the old English flaking hammer—now nearly obsolete—which has been shown to be identical in form with the stone tool used by neolithic man. These and other points of resemblance render it fairly certain that "at Brandon we have, as it were, an outlier of the Stone age—that the flint-knappers are the direct descendants of the old workers in stone, who dug the ancient pits at Grime's Graves, having preserved to this day the method of mining, the shape of sundry tools, and the peculiarities of certain flint implements."

X.

BRITISH INDUSTRIAL MINERALS.

Of all the countries of the world Great Britain is certainly the one most undermined by man. Nearly two hundred million tons of minerals are brought up every year to its surface from greater or less depths. With the vacancies thus produced in the bowels of the Earth, it is not surprising that land subsidences such as those lately noticed in Cheshire should occasionally occur. Our island has indeed proved well worth undermining, for probably no similar area of the Earth's surface possesses in such variety and abundance the most useful minerals and metals.

The manufacturing supremacy of this country is due, above all things, to its mineral wealth—to its coal and iron, its tin, copper, and lead. The great variety of its useful minerals and metals, and the vast extent to which some at least of these are annually drawn upon, may be most readily seen by a perusal of the Geological Survey publication

known as "The Mineral Statistics of the United Kingdom," annually prepared by Mr. R. Hunt. A new volume, dealing with the statistics for 1884, has recently been issued, from which it appears that the value of the minerals and metals obtained from the mines of this country during the year 1884 amounted to no less than sixty-one million sterling.

Seeing that gold is one of the most widely distributed of metals, it is not surprising to find that it has a place in British mineral statistics. Gold was formerly obtained in the tin streams of Devonshire, but now it is only found in a limited district of North Wales, the geological features of which are said to resemble closely those of the other auriferous regions of the globe. Of the numerous gold mines which have been started in North Wales there is, it has been said, probably only one which has not swallowed up more of the precious metal than it ever yielded—namely, that of Clogau, in Merionethshire, which attained its greatest productiveness in 1862, the gold extracted from the auriferous quartz during that year reaching the respectable figure of five thousand ounces. In 1884 the mine of Clogau was not worked, the yield during the preceding year having only amounted to sixty-six ounces.

The only other gold-producing locality referred to in these "Statistics" for some years past is that of Wicklow, the scene of intermittent gold-mining for nearly a century, and the locality from which the

largest British *nugget*—it is said to have weighed twenty-two ounces—was obtained. That the Irish have little to hope from their "gold diggings" is evident from the fact that during 1879 Wicklow only yielded two pennyweight eighteen grains of the precious metal!

Scotland, the fame of whose gold mines among the Leadhills in the reign of James V. attracted crowds of English and German adventurers, has for the present dropped out of the category of gold-producing countries, although only a few years ago a number of miners made a living out of the gold washings in Sutherlandshire. That small quantities of gold are annually obtained by the miners in the neighbourhood of the Leadhills, and sold to mineralogists and others desirous of possessing a specimen of Scottish gold, is well known, although it would be obviously impossible for the Mining Record Office to obtain accurate returns of the quantity thus collected.

Another source of the precious metals in this country is the cupreous iron pyrites now imported in large quantities from Spain and Portugal for the sake of the sulphuric acid manufactured from them. The cinders obtained after burning the pyrites for this purpose are afterwards treated for copper by a process of wet extraction, and from the copper liquors thus produced a considerable amount of silver and a small quantity of gold are obtained.

335,000 ounces of silver and 1,900 ounces of gold were thus extracted from over half a million tons of pyrites imported in 1884.

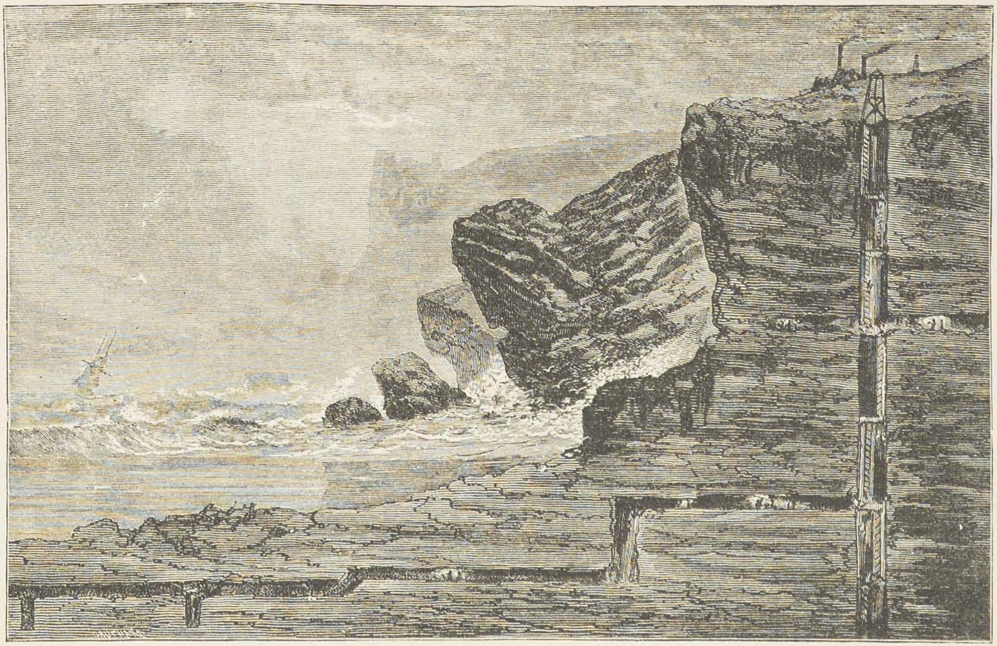
There is a single silver ore mine in Britain—that of Wheal Fortune, in Cornwall, which in 1878 yielded metal worth £6,000, but which only yielded silver to the value of £17 in 1882. The chief source of British silver, however, is lead ore, in which it occurs usually to the extent of about seven ounces of silver to every ton of lead. The proportion of the precious to the baser metal differs greatly, however, in different mines. Thus, in Northumberland, it is often less than two ounces to the ton, while in the Isle of Man it frequently exceeds thirty ounces. The quantity of silver extracted from lead ores in Scotland during 1884 amounted to 20,011 ounces; while the total amount of the United Kingdom was 325,718 ounces.

Lead is, after iron, the most abundant and most widely distributed of British metals. Lead mines —338 in number—are worked in nineteen English counties. They occur also in three Scottish and two Irish counties. These yielded in 1884 a total of 40,075 tons of lead—a decrease of about 2,000 tons over the yield of the preceding year. Of this amount 3,219 tons were Scottish—the produce of the Leadhills and Wanlockhead mines; while the Irish mines yielded 341 tons. Considerable as the home production of lead is thus seen to be, the

demand for it necessitated the importation during the year of an additional 110,000 tons, chiefly from Spain.

Tin, the quest for which led the Phœnicians to our shores more than two thousand years ago, in Britain is only found in Devon and Cornwall, and mainly in the latter, where its mining and extraction form the principal industry. These counties yielded 9,574 tons of tin during 1884—an increase of 250 tons over the produce of the preceding year—valued at nearly one million sterling. In early times Cornwall supplied the world with tin; now it cannot nearly supply the United Kingdom, 26,000 tons having been imported during 1884, chiefly from the Straits Settlements and Australia, the latter alone exporting more than the total produce of the English tin mines.

British copper is also chiefly obtained from Devon and Cornwall; but the total production of the United Kingdom in 1884 only amounted to 3,350 tons, valued at £203,000. Of this total Ireland yielded twelve tons, and Scotland *nil*; the copper mine of Sandlodge, in Shetland, which yielded six tons of metal in 1881 and ninety-six tons in 1880, having been for the present stopped. Copper ores and regulus are largely imported into this country, where they are smelted; and from this source alone 53,000 tons of metal were obtained in 1884, while of copper itself over 40,000 tons were imported.



SECTION OF TIN AND COPPER MINE, CORNWALL.

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Another metal, obtained wholly from Devon and Cornwall, is arsenic, of which 7,905 tons, valued at £58,000, were produced in 1884. Although popularly associated with villanies and vermin-killing, arsenic finds extensive use in the arts and manufactures. It is a leading ingredient in "emerald green" and other arsenical pigments. It is also employed in pyrotechny and glass-making, and a Devonshire dealer recently stated that he had taken an order for four tons of it, to be used in the manufacture of dolls' eyes.

Manganese is another metal of which little is known popularly, but which finds extensive use in the arts. It is largely employed in the manufacture of chlorine for bleaching powder, and also for mixing with iron in the making of Bessemer steel. The British yield of manganese ore has greatly declined of late years, 909 tons being the total produce of the year 1884, or about one-eighth of what it was ten years ago. The imports for the year, however, amounted to the large total of 26,046 tons.

There are fifty-two zinc mines in Britain, which yielded altogether in 1884 9,919 tons, valued at £74,029. Of this the single Scottish zinc mine, that of East Black Craig, in Kirkcudbright, which yielded twelve tons in 1882, produced nothing, while the Irish mine in County Wicklow yielded eleven tons. During the same period zinc was im-

ported to the value of one and a quarter million sterling.

The most important of British minerals is coal, of which 161 million tons were raised during 1884, being a decrease of three million tons on the preceding year. Their money value at the mines is estimated at forty-three and a half million sterling. When the "coal question" was being warmly discussed a few years ago, those who predicted the early exhaustion of that mineral based their calculations on the assumption that the consumption of coal would continue to increase at the same rapid rate at which it had been doing for many years before. Subsequent experience, however, does not altogether bear out this calculation. This want of elasticity in the coal trade is no doubt mainly owing to a succession of industrially bad years; it is more satisfactory, however, to know that it is, to some extent at least, due to increasing economy in the use of coal, especially in the manufacture of iron. Thus in 1840 three tons ten hundredweights of coal were consumed in the making of a single ton of pig-iron; the introduction of improved processes, however, so reduced this that in 1876 only two tons eight hundredweights were necessary, while the statistics for the past year show a still further reduction to slightly over two tons one hundredweight. Economy of coal has probably not yet reached its utmost limit in the mining and metal-

lurgical industries, which together consume annually about fifteen-fortieths of our entire coal supply; still less has it done so with regard to purely domestic consumption, which alone absorbs a fourth of our coal. A saving in this latter respect will probably be effected should the electric light succeed in superceding gas light, eight million tons of coal being at present annually converted into gas. An economy both of coal and iron is also likely to result from the rapidly-increasing use of steel for railway and other purposes, owing to its immense superiority over iron in point of durability. The extent of this increase is seen in the fact that the production of steel in Great Britain has grown from 245,000 tons in 1870 to 1,800,000 tons in 1884. This mighty impetus is no doubt due to the cheapness with which steel can now be produced by the Bessemer process.

Of the total quantity of coal raised in the United Kingdom, Wales produces nearly as much as Scotland, while together they scarcely contribute a fourth of the total output. Ireland is not without its collieries, having forty-seven of them scattered over its four provinces. Their total production, however, was only 122,000 tons, or about the yield of a single English colliery. Irishmen would probably have clung less tenaciously to the surface of the soil had there been anything of value beneath it to engage their energies, but unfortunately Ireland is singularly destitute of all kinds of mineral wealth.

Another form of carbonaceous mineral, which, from being a waste material, has grown into importance as a source of paraffine and ammonia, is oil-shale, almost the whole output of which is obtained from the lower carboniferous strata of Scotland. The total production of oil-shales during 1884 is stated to have been one million and a half tons, of which England supplied only fifty thousand tons. Of the rest Midlothian and Linlithgow produced over half a million each, and Fifeshire and Renfrewshire the greater part of the remainder.

Among the bituminous shales of the Lias of Yorkshire, jet, which is merely a lustrous variety of lignite or brown coal, occurs, especially in the neighbourhood of Whitby—the seat of the jet ornament manufacture—where, during 1879, three tons of this material, worth about £1,000, were obtained.

After coal, iron is the most important of British minerals, the money value of the yield of it during 1884 being almost exactly nine times that of all the other British metals combined. Five and a half million tons of iron, valued at thirteen and a half million sterling, were produced in 1884 from sixteen million tons of ore. The manufacture of steel by the Bessemer process continues, although the production in 1884 was less by 250,000 tons than that in 1883. The advantage of the Thomas-Gilchrist dephosphorization process is seen in the fact that, since its introduction in 1881, nearly

900,000 tons of steel have been manufactured from the phosphoric iron of Cleveland, which previously was unfit for steel-making.

After coal and iron, the most valuable mineral raised in Britain is salt, of which 2,332,704 tons were produced in 1884, more than four-fifths of it having been obtained from the salt mines of Cheshire.

The produce of the slate mines is also included in the "Mineral Statistics." Slates are chiefly obtained from Wales, and notably from Penrhyn and Llanberis, in Carnarvonshire; also from Ballachulish, in Argyllshire. The total produce of the 126 slate quarries in the United Kingdom in 1884 amounted to 485,664 tons, valued at one and a quarter million sterling, the quarrying of which is stated to have given employment to 16,000 people.

Among the miscellaneous minerals, of which comparatively small quantities only are obtained in this country, occur manganese, nickel-ore, wolfram, uranium, bismuth, barytes, gypsum, coprolites, and phosphatic nodules. Of the latter, used by manure manufacturers in the preparation of their "superphosphates," the English supply—almost wholly obtained from the crag and greensand of Suffolk and Cambridge—is every year growing less; while our imports, chiefly from Charlestown, United States, are yearly increasing. Few countries of equal extent are so rich in useful minerals as Great Britain; and it is due to the manufacturing skill and energy

which the possession of these has called into activity that our mineral wants have in so many cases altogether outgrown the native supplies.

A class of minerals not referred to in the "Statistics," and very sparingly represented in Britain, is that of precious stones. The diamond, sapphire, ruby, turquoise, and opal are wholly absent, not only from Britain, but from Europe generally. Such gems as occur are, as might be expected, found chiefly in the ancient rock formations of Scotland. The Grampians are their chief storehouse. It is not generally known that the topaz occurs in Britain; this it does, however, in the south-eastern corner of Aberdeenshire, in the drusy cavities of the rocks of Ben Macdhui and neighbouring peaks. They were formerly collected in such localities as the beds of streams; and an Edinburgh lapidary informed the writer that his father had at one time the sole right to seek for topazes on the estate of Invercauld. The Highland topazes are of a sky-blue colour; and one specimen in the Edinburgh Museum of Science and Art, supposed to be from Invercauld, is nearly as large as a pigeon's egg.

The true emerald does not occur in Britain; but the beryl, a closely-allied species, is found in the granite of Wicklow and Aberdeen. The Scottish beryls possess that sea-green tint that has gained for them the name of "aquamarines." There are several varieties of quartz or rock-crystal found in

Britain that are entitled to be regarded as precious stones. The amethyst, a violet-blue variety, occurs in drusy cavities among the Grampians, in trap-rocks on the coast of Haddington opposite the Bass Rock, and in the cavities of agate nodules. Smoky quartz, in which the brown or wine-yellow colour is due to the admixture of a minute portion of oxide of iron, is found in the Grampians chiefly in the neighbourhood of Cairngorm; and from the circumstance that the finest specimens came from that locality the cut stone has been called "cairngorm" by jewellers. Crystals from Cairngorm are sometimes very large—masses weighing twenty-five pounds have been obtained; and an Edinburgh lapidary is stated to have cut nearly £400 worth of ornamental stones out of a single crystal from that locality. It is chiefly used in Scottish jewellery for setting in the handles of dirks, the tops of snuff-boxes, and in plaid brooches. By arranging the facets of the stone around the table, so as to keep it as thick as possible, the lapidary secures great brilliancy combined with depth of colour in the cairngorm.

Agates are peculiarly Scottish, so far as Britain is concerned; and although they are smaller than those found in such localities as Oberstein and Uruguay, they probably surpass all others in variety of colour and delicate markings. Galston, Montrose, and Kinnoul Hill, are the best localities for the

"Scottish pebbles." Bloodstone or heliotrope is simply chalcedony mixed with green earth and spotted red with oxide of iron. The finest bloodstones come from Southern Asia; but they are also found, although of inferior quality, in the island of Rum and at the Mull of Cantire.

Visitors to the Fife coast can scarcely fail to have heard of or to have seen "Elie rubies," the gathering of these tiny gems being a favourite occupation of the summer visitors to that picturesque watering-place. They are not true rubies, but in lustre and colour they make the nearest approach of all British stones to that fiery Oriental gem. Elie rubies are in reality pyrope, a variety of garnet. The mineral, says Professor Heddle, "is now found only in chips among the sea-gravel, and very rarely embedded in the trap tufa. Formerly it was obtained in greater quantity, larger fragments, and also crystallized......Though the Elie pyrope has a little too much of the port wine shade of colour, yet its lustre is fine, and, weight for weight, it unquestionably is the most valuable Scottish gem."

XI.

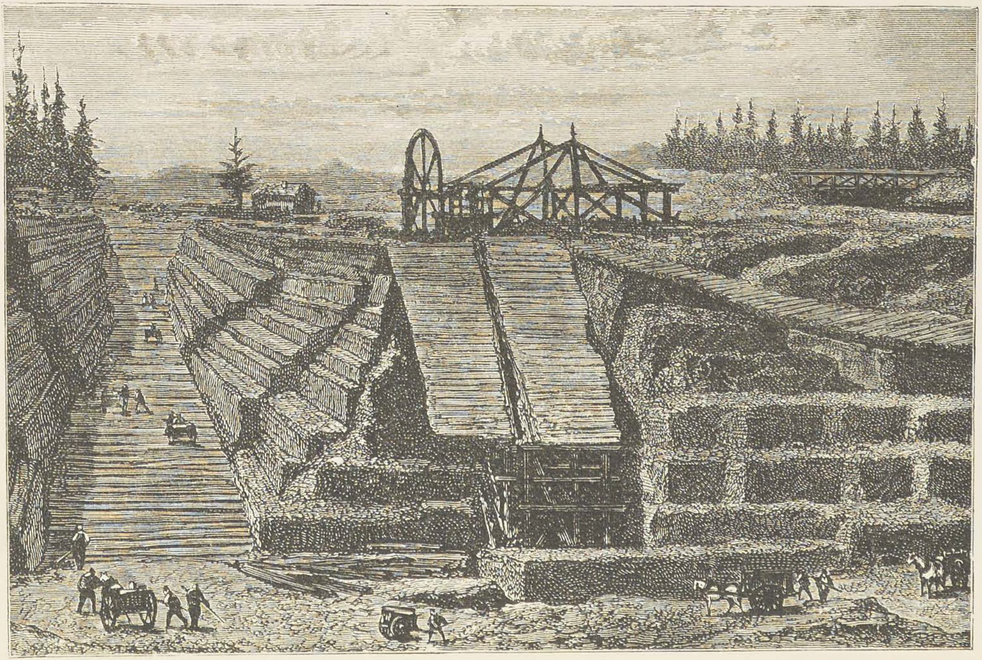
THE GOLD PRODUCTION OF THE WORLD.

ALTHOUGH among the scarcest of metals, gold is one of the most widely distributed. It is present to the extent of nearly a grain in every ton of ocean water, and there are few lands which cannot boast of their auriferous deposits; in equally few, however, can these be profitably worked. England has its auriferous quartz reefs in Merionethshire, which in 1863 yielded five thousand three hundred ounces of the precious metal; although of these it has been said that more gold has been put into them than has ever been taken out. Exactly three hundred years ago the Leadhills "diggings" were being vigorously worked by Sir Bevis Bulmer; and it was of gold obtained from these washings that the regalia of Scotland was made, as also the coins known as "bonnet pieces." The Leadhill miners still, when out of employment, can earn something under a shilling a day by washing gold out of the river sand, and selling it to collectors of Scottish

minerals at thrice the price of the foreign article; and the gipsies are said occasionally to eke out their living by thus operating upon the auriferous sands of the Rhine and Danube. The river Tagus was said to have rolled over golden sands, and it is altogether probable that much of the gold of ancient times was thus obtained from the beds of streams.

At the present day gold-mining cannot be considered a lucrative business. In spite of the many millions sterling which have been drawn from the mines of California, it was recently stated, by a competent authority, that looking to the shafts sunk, and the branches and tunnels driven, it would be found that "rather more had been put into the ground in the shape of labour than came out of it altogether in the shape of gold and silver." Pointing in the same direction is the fact that of the two and a quarter million sterling of English capital at present invested in gold mining, more than half yields no dividend, while in recent years the annual amount of gold raised in Victoria has not averaged more than £80 to £90 for each miner employed.

The total gold production of the world has of late years been declining, probably owing to the gradual exhaustion of alluvial gold deposits. This is especially the case in the chief gold-producing colony of Australia—Victoria—where the production has fallen to little more than half the quantity obtained ten years ago. The total yearly produc-



GOLD DIGGING IN THE URAL MOUNTAINS.

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tion of the precious metal, however, still amounts to upwards of twenty million sterling; the average annual amount since 1851 having been about twenty-four million. Before the discovery of gold in California and Australia, the Russian Empire was the chief source of supply, and at the present time it yields annually not less than eighty-five thousand pounds of gold, worth from three to four million sterling. The United States—chiefly California and Nevada—is at present the principal gold-producing country of the world; its annual yield being valued at eight million sterling, about a third of which is taken from two mines in the Comstock lode. Australia follows next, with five and a half million, New Zealand with a million and a quarter, while the gold-production of all other countries amounts to about four million sterling.

Amidst much recent prospecting, new gold fields have been neither numerous nor important. The Wynaad of India is rather to be regarded as an old field rediscovered, former workings having been traced all along the face of the hills. It presents an enormous development of auriferous quartz, identical, it is said, with that found in Australia; and, from assays that have been made, apparently equally rich in gold, the average yield at the works of the Alpha Company being ten and a half pennyweights per ton. For the success of almost any

gold field there must be, as Mr. Hyde Clarke pointed out at a recent meeting of the Society of Arts, facility of access, a good supply of suitable labour, and, above all, plenty of water. In these respects the Wynaad is probably more favourably situated even than Australia; and provided European capital and skill can be induced to enter the field—and already twenty companies are formed—there is not much reason to doubt that the mines of Southern India may yet prove an important source of gold supply. They would also increase the native supply of silver—a metal which India at present drains in large quantities from Europe—the gold of Wynaad being naturally alloyed with fifteen per cent. of that metal.

During the past two years gold-digging has been prosecuted with unusual success in Tasmania, where fresh alluvial deposits and gold-bearing quartz reefs have been recently discovered. A few years ago, gold was found in considerable quantities in surface deposits in the Transvaal, and a nugget weighing eleven pounds was obtained. Auriferous reefs were also discovered; but difficulty of access, and, still more, the unsettled condition of the country under a weak Boer government, prevented the development of a highly-promising gold field. Capital and European direction only are needed to develop the gold resources of this South African El Dorado, and under British rule these are not likely to be long awanting.

European countries, although now, as already said, yielding comparatively little gold, seem in early times to have been chief sources of the precious metal. This was the case with Spain, which, according to Livy, yielded the gold of which the splendid ornaments worn by the Roman matrons was made. During the three hundred years of Roman occupation the Iberian peninsula yielded to its conquerors twenty thousand pounds of gold annually; to obtain which sixty thousand slaves and prisoners of war are said to have been employed in the gold mines. The Arabs long afterwards drew great wealth from the same source.

In what parts of Spain were those productive gold mines situated? and were they exhausted by those early miners? In answer to these questions, an interesting paper was read by Mr. Wm. Sowerby at a recent meeting of the Society of Arts, London. He places the auriferous region in the north-west of the peninsula, on the southern flanks of those cordilleras that run through the provinces of Leon, Galicia, and Asturias. Here, over a region of from four thousand to five thousand geographical square miles, are immense deposits of gold-bearing gravels and conglomerates. Numerous old galleries, believed to be Roman, have been discovered, driven far into the gravel; also the remains of canals by which those ancient workers brought from great distances the water required for their gold-washing operations;

and at the city of Ponferrada—the centre of this auriferous region—some ancient Roman cupella for smelting gold have been found. Mr. Sowerby's purpose was to show that neither the Romans nor any miners since had tapped more than a small portion of these auriferous gravels, and that even the "tailings" of former times would, when attacked by modern appliances, yield a profitable percentage of gold. The gravel which has been formed by the denudation of the surrounding mountains attains in many places an enormous thickness, that of Las Medulas having a depth of eight hundred and fifty feet—a thickness seldom equalled in any similar deposit of gold gravel known in any other part of the world. Nuggets, occasionally an ounce in weight, occur in the gravel, and are picked up by the shepherds and labourers. Most of the gold, however, is fine flour gold, and the finer it is the more plentiful it seems to be.

The discovery of America, with its immense gold resources, by the Spaniards in the fifteenth century, probably diverted their attention from the poorer deposits of their own country. On a small scale, however, gold-seeking is believed to have gone on continuously since Roman times. In a portion of the valley of the Sil, known as the Valde Orras, or "valley of gold," every flood brings down a fresh crop of gold in the sand; and every year, according to Mr. Sowerby, the natives take a spell for a few

weeks at the gold washings. There are likewise one or two villages in Las Medulas with a population distinct from the other Spaniards, and supposed to be the descendants of the old miners. They are said to collect about £5,000 sterling annually of gold from the streams in their neighbourhood.

It is not to be supposed, however, that in this north-western portion of Spain a second El Dorado has been discovered. The auriferous deposits are extensive, and the entire quantity of gold contained in them must be large, but it is thinly spread out. A great deal of washing must be done for a very little gold. The better appliances now in use, however, for this work enable low grade deposits to be dealt with at a profit; and with the abundant supply of water to be had at all times in this corner of Spain, the few pennyweights of gold per ton of gravel, which is all that can be reckoned on, may prove remunerative. Spain is rich in minerals, and British capital has done much to develop its metalliferous resources; it is possible that a new field for our enterprise may be found in continuing the work of the Romans among the gold gravels of Spain.

While attention is thus being drawn to the old gold fields of Spain, miners are busy developing a new gold field in Norway. Scandinavia has not hitherto yielded much gold. It was discovered in Lapland in 1867, and about one thousand ounces

annually have since been obtained from that source. In a small island at the entrance to Hardanger Fjord, named Bömmelöen, a piece of gold was picked up twenty years ago, which found its way to the Mineralogical Museum at Christiania. Nothing further, however, came of this "find;" probably it had escaped the notice of English mining engineers. Gold was again found two years ago in one of the mines worked for copper ore. The news spread, and in 1883 the works were purchased by an English firm trading under the title of the Oscar Gold Mining Company. The place has suddenly been transformed from a desolate and almost uninhabited island into a busy scene of extensive gold digging. "Numerous English artisans," says a writer in *Nature*, "and Norsk bricklayers and carpenters have for months been actively engaged in boring and sinking shafts into the rock, and in preparing houses and shelter for the men and machinery." The gold occurs in quartz veins not more than six feet in thickness. The news of gold-finding in Bömmelöen has so quickened the search for it throughout Norway, that its discovery has since been reported from other three localities.

The recently issued report of the Department of Mines, Nova Scotia, for 1883, brings into notice a comparatively neglected gold field. Nova Scotia is in the peculiarly fortunate position of possessing in juxtaposition coal, iron, and gold; but these

resources it cannot yet be said to have adequately developed. The area of the auriferous districts is estimated at about three thousand square miles, gold occurring, according to Mr. Gilpin, Inspector of Mines, in quartz lodes containing "spots and bunches of the free metal of every shape and size up to sixty-ounce nuggets." Some of these lodes are much richer in gold than others; thus the Rose lode has yielded four ounces to the ton of quartz, while the average yield during 1883 was only ten penny-weights twenty-one grains per ton crushed. Occasionally, also, "pockets" occur of exceptionally rich material, so that one crushing of thirteen tons has been known to yield two hundred and thirty-four ounces of gold. There are also large drift deposits, in some cases fifty feet deep, but alluvial gold digging has not as yet been much prosecuted. Nova Scotian gold, like that of other countries, is an alloy in which silver is the chief impurity. It is, however, exceptionally pure, one thousand parts having been recently shown to consist of nine hundred and eighty-five parts of pure gold and fourteen and a half parts of silver.

Gold mining in Nova Scotia dates from 1862, since which time an average of about sixteen thousand ounces of gold have been extracted yearly from an average of fully twenty thousand tons of quartz. The yield during 1883 amounted to fifteen thousand four hundred and forty-six ounces—

the largest return since 1871. The lowest yield at any of the gold districts was seven pennyweight twenty-two grains per ton, while the highest was three and a quarter ounces. The work of gold extracting in Nova Scotia has for the most part been carried on in a most wasteful and unscientific manner; the loss having been estimated in some cases at one-half of the total quantity of gold contained in the quartz. Speaking of the mines in the Oldham district, Mr. E. Jack states, "No one has ever yet attempted to utilize the 'tailings' from the stamp mills; these contain a large quantity of auriferous sulphides." He estimates that at Oldham alone there are ten thousand to twenty thousand tons of these "tailings," calculated to yield from 8s. to 21s. sterling per ton; and Mr. Gilpin, in one of his reports, states that by neglect of these auriferous sulphides over a million dollars has been thrown into brooks and swamps during the last eighteen years. In spite of this waste the average yield of gold per ton of quartz is higher than in almost any country mining quartz lodes. The mines only require to be worked in a systematic and scientific manner, and with the appliances now available, in order to render gold mining in Nova Scotia a highly profitable operation.

The world's gold is almost wholly obtained *native*, although of late years small quantities have been extracted in Colorado and California from the

minerals known as graphic tellurium and calaverite, the former of which contains twenty-five and the latter forty-two per cent. of gold. Native gold is got either by washing it out of the alluvial soil or by crushing it out of the quartz rock, through which it is disseminated, for the most part, in invisible particles. In the former case, the operation is comparatively simple, and a very small quantity of gold per ton remunerates the miner. Thus the proportion in Siberia is from twelve to thirty-six grains per ton, in Australia twenty-five grains, and in California only twelve. About a third only of the Australian gold is now obtained from those surface deposits, but two-thirds of that from California is alluvial. The large quantity in the latter case is due to the almost exhaustless deposits of auriferous sand and gravel which form a series of terraces bordering upon the river channels, and which occasionally attain a thickness of over a thousand feet, with a width of a quarter of a mile. To disintegrate these conglomerate gravels the Americans have devised the hydraulic method. Bringing water in a hose from a reservoir placed at a considerable height to give force to the stream, they attach to it a nozzle, from which the water issues with a force that makes it feel like metal to the touch, and which, according to Dr. R. Brown, is strong enough to kill a man instantly, and to tear down a hill more rapidly than a hundred men with shovels.

Several of these pipes directed against a gravel bank soon cause it to crumble and fall in large masses, although to facilitate the operation it is usual to loosen the gravel by a gunpowder blast. The gigantic scale on which these operations are carried out may be gathered from the fact that for a single blast as much as fifty tons of powder will sometimes be used. The material thus disintegrated is swept by the current of water into the "sluice-boxes," where the greater part of its auriferous contents is deposited. One unfortunate result of those hydraulic operations is the number of accidents to life and limb arising from sudden gravel-slips, the deaths from this cause alone being, it is said, not less than eighty to ninety per annum. The shoaling of the two chief rivers of California through the rapid deposition of mud, and the consequent danger to navigation, is another undesirable result. These and all other alluvial deposits, no doubt, owe their gold to the disintegration of quartz and other rocks through which it had been disseminated.

There is still, however, an abundance of undecomposed auriferous reefs, and probably nearly one-half of our annual supply of gold is now obtained from this source, man doing, by means of crushing machinery, the work which nature has thus been performing on a gigantic scale for ages. Expensive machinery and skilled labour are required for crushing the quartz and separating the gold; a larger

proportion of the precious metal is therefore required to render quartz-crushing as remunerative as alluvial digging. That gold mining of this kind has so often proved unprofitable would appear, from a valuable paper by Mr. Lock on this subject, to be due less to the want of a paying quantity of gold in the rock than to the failure of the machinery employed to take a remunerative quantity out of it. He states that in New Zealand no gold-mining company has been able to pay a dividend from ore containing less than ten pennyweights per ton; the reason being, that through want of proper appliances much of the gold is allowed to escape. Where effective machinery is employed, he shows that rock much poorer in gold can be, and is, profitably worked. In one instance this result was attained from quartz containing only two pennyweights eleven grains of gold per ton; while the most remarkable case of all is that of the Imperial Company of Ballarat, who have treated large quantities of quartz containing only twenty-two grains of gold per ton "with a fair margin of profit on the operation."

Gold frequently occurs in quartz and other minerals in intimate association, although not chemically combined, with certain metallic compounds, chiefly those comprehended under the general term "pyrites," and in Brazil the pyritous ores form the chief source of the precious metal. Considerable difficulty attaches to the separation of gold from

these baser metals, and in Australia the auriferous pyrites were formerly to a large extent thrown aside in the "tailings" as not worth the trouble of further manipulation. The less remunerative character of gold mining lately in Australia, and the perfecting of processes for the thorough and economical extraction of gold from all sorts of auriferous ores, have led to the general utilization of the waste pyrites, and to the recovery, it is said, of from ninety-five to ninety-eight and a half per cent. of the contained gold. That much remains to be done in this direction is seen from the fact, recently stated, that in American mines an average of twenty-five per cent. of the gold contained in the rock is allowed to escape, one of the best Brazilian mines never recovering more than from seventy to seventy-three per cent.

It was supposed, not many years ago, that auriferous quartz did not extend far beneath the surface. This, however, has been disproved by the depth to which gold mines are now profitably worked in Victoria, several of these having a vertical depth of over two thousand feet, and the deepest—that of Magdala—2,273 feet. They are thus worked at greater depths than are most of our own coalfields. The rock was also supposed to become less auriferous the further it went from the surface. There are mines, however, in California which have become richer instead of poorer with increased depth. In

the thorough working of the practically exhaustless storehouse of gold contained in the auriferous rocks, and not in alluvial "diggings," which in Australia are already showing signs of exhaustion, lies the hope of a continuous and sufficient supply of the metal so essential as a circulating medium to the commercial prosperity of the world.

XII.

THE COMSTOCK SILVER MINES.

AMONG several causes which have led to the recent depreciation in the value of silver, the most important has undoubtedly been the development of silver mining in the "Far West" of America, and especially the discovery and working of the Comstock lode in Nevada, which has been to the production of silver in the present century what Potosi and the Mexican mines were in former times.

Twenty-five years ago a couple of miners engaged in gold-washing at the foot of Mount Davidson, in the western corner of Nevada, came upon a rich vein of the sulphuret of silver in a pit dug for the purpose of collecting water for their gold-washing operations. The "claim" on which the discovery was made was bought up by a man named Comstock, from whom the lode afterwards took its name. The news of the "find" spread rapidly among the mining population of the States, and prospecters flocked from all quarters to the new argentiferous

region; locations were made along six miles of the supposed lode, and in a couple of years Virginia and Gold Hill cities, with a population of fifteen thousand to twenty thousand people, had sprung into existence.

The main Comstock lode is known to exceed twenty-two thousand feet in length, and to give off several important subsidiary veins. Large portions, however, of the intrusive mineral matter of which it is composed are altogether deficient in metallic ores, the richer silver ores occurring in what are known as "bonanzas," corresponding to the "pockets" of the Cornish miners. One of the most productive of these, which occurs at a depth of thirteen hundred feet below the surface, is seven hundred feet in length, five hundred feet in depth, and ninety feet in thickness, and has during the past six years yielded no less than a million tons of ore, valued at about nineteen million sterling. The various excavations in this lode now give employment to upwards of three thousand miners, and their average daily output of ore amounts to two thousand tons. Although this is chiefly valuable for the silver it contains, it also yields a considerable percentage of gold, the resulting metal usually consisting of about ninety-four per cent. of the former and six per cent. of the latter. The value of the precious metals drawn from the mines of Nevada during 1877 amounted altogether to twelve million sterling, of

which the Comstock lode alone yielded nine million, while it is estimated that the total yield of the vein since its discovery in 1859 must have exceeded eighty million sterling.

Whence, it may be asked, have come all the gold and silver found in the Comstock lode? The favourite theory now is, that all such veins derive their metallic constituents from the surrounding rocks, minute quantities of the precious metals having been found in augite, mica, and other rock-forming minerals. The rocks surrounding the Comstock lode are mainly diabase and diorite, and Mr. Becker, one of the United States Geological Survey officers, examined these for silver and gold, when careful analysis showed that both were present, especially in the diabase. The latter consists of the minerals augite and plagioclase, and it is in the augite that the precious metals chiefly occur. Mr. Becker's opinion is, that the silver, and probably also the gold, of this famous lode must have been derived mainly by chemical agencies operating for untold ages upon the augite of the older diabase. "Verily," says Professor Rudler, commenting on this conclusion, "it needs a firm faith in the value of accumulated trifles to believe that a mineral like augite, popularly called 'non-metallic,' and reputed to have little or no economic value, may nevertheless represent a potential mine of gold and silver."

Important economically as the richest in the

world, the Nevada mines are interesting scientifically as the hottest. Shafts have been sunk to a depth of over two thousand feet, and in the lower levels of these the rock, according to Professor Church, who has made a careful study of the heat phenomena of the Comstock lode, has a temperature of about 130° F., freshly exposed surfaces being painfully hot to the touch. The air is artificially supplied from the outside, and therefore rarely has a temperature exceeding 110° F.; the heat of the water, however, of which the mines unfortunately have a superabundance, is greater even than that of the rock, being often as high as 150° F. The water which recently inundated one of the mines, and a million tons of which were pumped out in a single year, had, it is said, a temperature of 154°, while in another instance a heat of 158° was noted in the water of a level eighteen hundred feet deep. Professor Church states that annually four million tons of water are pumped from these mines, all of which is at least 85° above the outside temperature; an excess of heat which to supply artificially would require the combustion of nearly forty-eight thousand tons of anthracite coal. On the other hand, fourteen thousand four hundred tons of air, at an average temperature of 50°, are daily poured by the ventilating machinery into the shafts and galleries, from which it emerges 42° hotter than when it entered—an excess of heat correspond-

ing to an expenditure of eight thousand tons of coal.

Not the least remarkable feature in the phenomenon under consideration is the want of uniformity in the temperature of the lode, some of the higher levels being much hotter than others at a greater depth. Certain hot areas—not placed promiscuously, but, as Professor Church inclines to believe, lying in regular belts—occur at varying depths throughout the mines, while in other parts the equally puzzling phenomenon of unusually cold rock is exhibited. These cold belts are fewer in number than the hot; they are always wet, and have a very perceptible influence in lowering the surrounding temperature. "They complete," says the writer already referred to, "a well-linked chain of heat phenomena, extending from rocks that are sensibly cold to the touch, and may not have a temperature above 50° or 60° F......to those which have a temperature of 157°."

Scientific men have not yet agreed upon an explanation of the remarkable heat phenomena of the Comstock lode, although the theory that such high temperatures are a remnant of the heat once possessed by those comparatively recent volcanic rocks when in a molten state, is the one most generally accepted. Professor Church, however, rejects it as incapable of explaining the known facts, and substitutes for it the hypothesis that the

heat is due to active chemical action now going on in the erupted rocks. The latter in the vicinity of the lode are being gradually converted, under the influence of air and moisture, into clay; the decomposition thus taking place being necessarily accompanied by an evolution of heat analogous to that which takes place when calcined lime is slaked with water. In the hot belts of the Comstock mines, decomposition, according to this theory, is in active progress; in the cold areas, again, owing probably to differences in the texture of the rock, decomposition has been retarded, while the greater portion of the rocks, from the surface to a depth of a thousand feet, may be regarded as already burned out.

Immediately on the appearance of this theory it was attacked by Mr. J. A. Phillips, who sought to show that the supposed chemical action was altogether inadequate to account for the thermal phenomena; and in this contention he has been supported by Dr. Barns, the physicist attached to the United States Geological Survey, who put it as far as possible to the test of experiment. Both of these physicists are inclined rather to regard the high temperature of the Comstock lode as a relic of former vulcanicity.

Whatever be the cause of the heat—and other theories besides those mentioned have been brought forward—its effects are painfully felt in the practical working of this mammoth lode. Fatal accidents

are not uncommon, and of the fifty-three which occurred during the twenty-two months previous to May 1877, no fewer than seventy-three per cent. were directly due to the effects of heat. In a few cases miners have been scalded to death by falling into the hot waters of the mines. Prolonged exposure in the hotter areas frequently produces fainting, but this most frequently occurs just as the miner, in making his ascent, reaches the cooler air, about one hundred and fifty feet from the surface. So many fatal accidents used to occur owing to this circumstance, that no man who has been working in a hot drift is now allowed to go up alone. Those unaccustomed to the work are often brought to the surface speechless and dazed; effects which in most cases rapidly pass off, although occasionally there are cases of permanent loss of memory, of insanity, and of death resulting from this cause. To give a single instance from the many adduced by Professor Church:—A man, who had gone to work for the first time in the Imperial mine, was cautioned against over-exerting himself in the extreme heat of the lower levels. To this, however, he paid no attention, replying that he thought himself strong enough to stand anything. "At half-past two in the afternoon he was brought to the surface in an unconscious state, and died the next morning at half-past ten o'clock." In order to "cool off," as they call it, the miners either expose themselves to cold

currents of air or drink copious draughts of iced water; and although fatal results have been known to occur from the practice of such summary methods, yet these, it must be added, are remarkably rare. The ice, of which many thousand tons are annually consumed, costs the mining companies twenty dollars a ton, and thus forms a considerable item in the working expenses.

In order to facilitate mining operations in the Comstock lode, it was determined sixteen years ago to drive a tunnel into the mountain side, which would tap the vein at a depth of eighteen hundred feet beneath the surface, and which by means of branches would be brought into connection with, and would form a common highway for, all the mines on the Comstock lode. Better ventilation and a reduced temperature it was hoped would thus be obtained, as well as a natural system of drainage through the tunnel for all the water above the eighteen hundred feet level; thus doing away with much of the pumping, which has in recent years entailed an annual expenditure of half a million sterling. A highway would thus also be obtained for the conveyance of ores to the reducing mills outside, greatly cheaper than the costly method of raising them to the surface; and therefore available for the carriage of the poorer ores, which, owing to excessive working expenses, have hitherto been left untouched.

The work of cutting the Sutro tunnel, as it is called, was begun in 1869, and has been carried on amid a variety of obstacles with the usual American energy. Drilling machines such as those used in the Alpine tunnels have of late years been employed; but the enormous deposits of clay frequently encountered have proved more difficult to deal with than the hardest rock. Not only was this tenacious material difficult to pass through, but on exposure to the air it frequently swelled to such an extent as, according to one authority, "to displace the railroad track, and to break the stoutest timber like reeds." Some time ago the main part of the work was completed by the opening of the tunnel into one of the mines on the Comstock lode, the distance from this point to its entrance at the town of Sutro being a little over twenty thousand feet, or about four miles.

The tunnel is as straight as an arrow through its entire length, and forms a spacious roadway fourteen feet in width and twelve feet high, with a double set of rails, beneath which lies an enclosed drain to carry off the heated waters. One of the anticipated advantages has already been realized in the improved ventilation of the only mine yet connected with the tunnel. No sooner was the connection formed than the draught of cool air from the outside made itself refreshingly felt; and in the workings at a depth of two thousand feet in this mine, the heat, which for-

merly stood at 120° F., now seldom rises above 90°.

The branches to connect the various mines in the lode with the main Sutro tunnel are now being pushed rapidly forward, and a few years will probably see the entire work finished. It is not too much to say, that without such a means of exit and entrance into the heart of Mount Davidson, it would have been impossible for the miners of Nevada to have ransacked the riches of the Comstock lode.

XIII.

THE SOURCES OF SALT.

THE President of the British Association, in his address at Swansea (1880), found in salt one of the aptest illustrations of his text that there is, geologically speaking, nothing new under the sun. Rapidly reviewing the various formations known to geologists, from the immensely remote Silurian down to the recent Tertiary, he found deposits of salt in them all; but he also found that salt was being formed at the present day in probably as great abundance as at any former period of the Earth's history. While thus affording evidence of the uniformity of Nature's operations, the salt deposits at present in progress supply the only trustworthy key to the mode of formation of the rock salt and brine springs of past ages.

The sea is the great storehouse of this mineral necessary of life, and there is good reason to believe that most of the salt of the earth has been originally derived from the briny deep. The sea is not every-

where of a uniform saltness; for while thirty-four parts in a thousand of water from the open ocean consist of salts—nearly four-fifths of these being common salt—there are parts of the ocean in which that proportion is not nearly reached, and others in which it is greatly exceeded. These are seas connected with the ocean only by narrow straits, and their degree of saltness is above or below the average according as the evaporation from their surfaces is greater or less than the quantity of fresh water poured into them by rivers. Thus, there are portions of the Baltic with less than ten parts of salt in a thousand of water; while in the Red Sea, where evaporation is enormous, and where there are no rivers to bring *fresh* supplies, the proportion rises to forty-three parts per thousand. That the former sea does not become altogether fresh, and the latter solidify into a block of salt, is due to the action of currents, which, to a certain extent, bring about an interchange of the waters of different seas. Thus there is a stream of highly saline water at a great depth constantly making its exit from the Mediterranean by the Strait of Gibraltar, while there is at the surface a corresponding influx of fresher water from the Atlantic. By this means the sea is prevented from ever becoming sufficiently salt to cause a deposition of its saline ingredients to take place at the bottom; and judging of the past by the present, it may be presumed that the salt deposits—in some

cases hundreds of yards thick—which are found in the geological formations of all ages, have likewise not been precipitated on the ocean floor.

The supersaturation necessary for the deposition of salt in the solid form is now, and has probably always been, brought about in salt lakes, in lagoons cut off from the ocean by sandbanks, and in inland seas. This is typically exemplified in that greatest of existing sheets of inland water—the Caspian Sea, where the most extensive salt deposits of the present period are in process of formation. Although it is now regarded as certain that the Caspian formed at one time a part of the ocean, from which, at a comparatively recent period, it was cut off by the upheaval of the intervening land, its waters are not nearly so salt as those of the nearest open sea. While this is partly due to the enormous quantity of fresh water which flows into it from the rivers Volga and Ural, it is mainly owing to the deposition of salt in the solid form which is constantly taking place in the shallow lagoons with which it is surrounded, and which, in the capacity of natural salt-pans, draw off vast quantities of the saline constituents of the Caspian water. A recent writer describes one of these, formerly a bay, but now divided into a number of basins, each of which illustrates a stage in the progress from salt water to rock salt. "One of these," he says, "still occasionally receives water from the sea, and has deposited on its banks only a

thin layer of salt; a second, likewise full of water, has its bottom covered by a thick crust of rose-coloured crystals like a pavement of marble; a third exhibits a compact mass of salt, on which are pools of water whose surface is more than a yard below the level of the sea; and a fourth has lost all its water by evaporation, the stratum of salt left behind being now covered with sand." A still greater salt deposit is in course of formation in the Karabhogas, a part of the Caspian with an area of three thousand square miles, and now only connected with the parent sea by a narrow opening in a sandbank. Through this passage the waters of the Caspian flow in a constant stream into the inner sea, where they are wholly dissipated by evaporation, their saline ingredients being left behind. In this way the Karabhogas Bay alone is said to withdraw daily from the Caspian Sea not less than 350,000 tons of salt, or about a seventh of the total annual production of the United Kingdom. That the waters of this greatest of the Caspian salt-pans have been gradually growing brinier is evidenced by the fact that the seals which used to frequent its waters are now no longer found. Life of all kinds, indeed, would seem to have deserted it, while a deposit of rock salt of unknown thickness is being formed on its bed.

There are many salt lakes, however, which, unlike the Caspian Sea, do not appear to be "survivals" of ancient oceans, and whose saltness must, therefore,

be due to the gradual accumulation in them of the exceedingly small quantity of saline matter contained in river and other waters flowing into them. River water usually holds in solution about one part of salt in every sixty thousand parts of water; and inappreciably small as this proportion appears, it nevertheless indicates an enormous quantity of salt borne seaward by rivers in the course of a single year. Thus the Thames annually washes from its channel and carries to the sea no less than forty thousand tons of salt dissolved in its waters. Were these discharged into an inland lake or sea without outlet, in which the evaporation was sufficient to carry off the surplus waters, the saline ingredients would inevitably accumulate until the water became supersaturated with them, when deposition would take place. This would seem to have been the case with the Dead Sea, which is generally believed to owe its high percentage of salt to the evaporation of the accumulated waters of the Jordan and of the numerous springs which go to feed it. The mud of the Dead Sea bottom is more or less covered with cubical crystals of salt and of other associated minerals deposited from its highly saline waters.

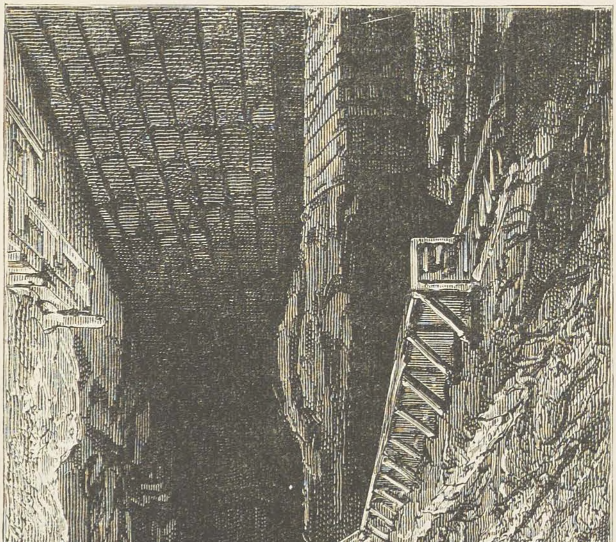
A considerable number of salt lakes occur in North America, the chief of these being the Great Salt Lake of Utah, the waters of which are fully seven times salter than those of the ocean. Its waters are simply brine; and when these are spread,

as they sometimes are, by storms over a wide tract of low-lying margin, the rapid evaporation which follows produces a solid crust of salt. Dr. Geikie, when visiting Great Salt Lake, bathed in its waters, and noticed that in raising his foot off the bottom some exertion was necessary to force it down again. So rapid also was the evaporation in the dry air of that region, that the skin after being wetted was almost immediately covered with salt. He noticed also that the wooden steps of the pier from which bathing operations were carried on were hung with slender stalactites of salt from the drip of the bathers.

Salt lakes are also plentifully scattered over the southern parts of South America, many of these being shallow lakes of brine in winter, and fields of snow-white salt in summer. Salt also sometimes appears on the surface of the ground as the result of the evaporation of the moisture beneath; certain parts of the great alluvial plain of the Ganges being, according to Professor Ramsay, rendered worthless for cultivation by an efflorescence of this kind. That the salt deposits to which the President of the British Association referred as existing in strata of all ages, arose in ancient salt lakes or lagoons through the evaporation of their liquid contents, just as they are forming at the present day in the neighbourhood of the Caspian, is also rendered probable by the mode in which fossil salt usually occurs—namely,

in small detached areas, such as might have formed the beds of lakes.

The chief salt deposits in Great Britain are those of Cheshire, from which about two million tons of salt are annually extracted; yet most of the saliferous district is comprised in an oval area about a mile and a half in length by three-quarters of a mile in breadth. These salt deposits of Cheshire are of Triassic age, although similar deposits have also been found of late years in rocks of Carboniferous age at Middlesborough-on-Tees. The salt of commerce is obtained partly in the solid state as rock salt and partly from brine, the latter being for the most part pumped up from the beds of rock salt beneath. There are about twenty-five salt mines in the United Kingdom, chiefly in Cheshire and Worcester, the most extensive probably being the Marston mine at Northwich. The underground workings in this case are about three hundred and fifty feet beneath the surface, and have an area of thirty-six acres, the roof of this vast underground hall being supported on one hundred and thirty one pillars of salt. The appearance of these salt pits is in pleasing contrast to that of coal mines, and they are frequently visited by large parties of excursionists, who view with delight the brilliant effect produced by the illumination of these underground palaces. The most ancient, the finest, and the most extensive salt mines in the world, however, are those at Wieliczka in Galicia. They



A CONTINENTAL SALT MINE.

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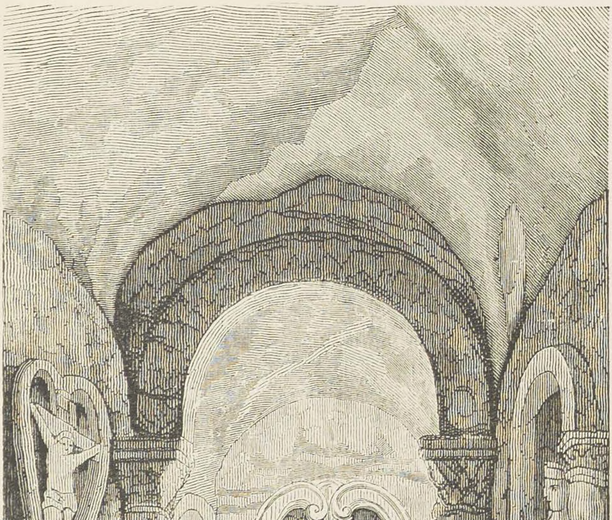
have been worked for many centuries, and now the excavations, which are 1,780 feet deep, extend for 10,000 feet from east to west, and 3,600 feet from north to south. The mines consist of four stories, one above the other, and in one of these the workmen have excavated in the solid salt a Gothic chapel containing numerous statues and obelisks carved out of the same material. The magnificent effect produced by lighting up this chamber and the Wieliczka mines generally has been frequently described.

River, lake, and sea water, however, contain other minerals in solution besides common salt; and if rock salt has resulted from the evaporation of such waters, it follows that the other substances dissolved in them should, as a general rule, appear in association with it. When sea-water is artificially evaporated for the production of salt, the carbonate and sulphate of lime—the latter frequently in the form of gypsum—are first precipitated; then follows the deposition of salt; and, lastly, from the liquid which still remains, known as "mother-liquor," a variety of salts of considerable importance industrially are precipitated. An examination of the ancient rock-salt deposits usually reveals the presence to a greater or less extent of these allied substances. Beds of gypsum and rock-salt are almost invariably associated, the gypsum forming the base on which the other rests; they also frequently occur in alternate layers, the result probably of periodic influxes of salt water,

the evaporation of which supplied a layer of each. Although less frequently found, the salts of the "mother-liquor" also occur deposited over the rock-salt. They are typically developed at Stassfurt in Prussian Saxony, where they are worked on a large scale, chiefly for the potash they contain. Bromine also occurs in small quantities in the salts artificially extracted from sea-water; and it is also found in those upper salts of Stassfurt, and in such quantity that the potash manufacturers of that town prepare annually upwards of fifty thousand pounds of bromine as a by-product of their industry.

The ocean, as has been already stated, is constantly receiving enormous quantities of salt washed out of the land and carried to it by rivers. These rivers are replenished by rain, and thus get returned to them the water, but not the salts, they brought down. Unless, therefore, there is some means of abstracting from the sea the salt thus added to it, the ocean must inevitably be growing salter. The life, both plant and animal, which the sea yields up, abstracts from its waters a considerable quantity of salt; so also does man; lagoons on low-lying shores, which are occasionally connected with the sea, are probably still more potent in the same direction; but all these put together seem scarcely adequate to neutralize the additions constantly being made to the amount of common salt in sea-water. If the sea be gradually growing salter—no matter how slowly—



CHAPEL IN THE SALT MINES OF WIELICZKA.

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may it not possibly have reached its present salinity from an initial condition of comparative freshness? Analysis, however, of the earliest rock-salt deposits —those of the Silurian—would seem to show that the composition of sea-water has undergone little or no alteration since that immensely remote period. This and other considerations have led a recent writer to conclude that "the first body of water on the Earth was not sweet water, but salt water"—a conclusion which, however probable in itself, rests, unfortunately, on an unverifiable hypothesis.

XIV.

OIL WELLS.

OVER twenty years have elapsed since Colonel Drake first "struck oil" in America. Petroleum springs, however, were not unknown before. St. Catherine's Well, near Liberton, was a famous resort of invalids three centuries ago, whatever virtue its waters possessed in the cure of cutaneous diseases being due to the constant presence on its surface of a small quantity of petroleum—an oil which it still continues to yield. It was from a petroleum spring issuing from the crevices of the coal in a Derbyshire mine that Mr. James Young first obtained, in 1848, the crude oil from which he extracted paraffine. It was only when this source "gave out" that, luckily for Scotland, he hit upon his method of obtaining artificially the crude oil by the distillation of shale, and thus established an industry whose rate of growth has been unparalleled in the history of our manufactures. At the present time, about one and a half million tons of shale are thus annually dis-

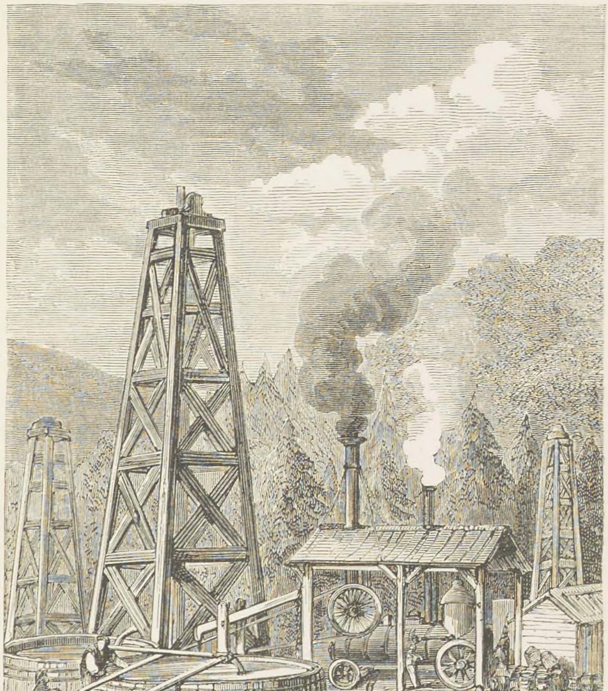
tilled in Scotland, yielding nearly forty million gallons of crude oil.

The method of thus obtaining mineral oil artificially affords a probable clew to its formation in nature. Petroleum occurs in strata of all ages, from the lowest fossiliferous formations to the most recent; but in these it is chiefly found in connection with beds of coal and other rocks of more or less organic composition; and the most probable theory of its origin is, that it has been naturally distilled from rocks in which ancient vegetable and animal life has been entombed, by the action on these of slow subterranean heat. On this theory, the oil which forms a scum on the waters of St. Catherine's Well is the result of nature's distillation of the same shales which are now being made to yield up their oil much more rapidly in the retorts that now abound in that neighbourhood.

During the millions of years which are supposed to have elapsed since the deposition of the richest oil-yielding strata, there has been ample time for the production and storage of vast quantities of petroleum; and that such accumulations have taken place the oil wells of America abundantly testify. The quantity of petroleum that has been raised in Pennsylvania since the first well was sunk in 1859 would seem to indicate the presence of vast subterranean lakes, which twenty-two years of constant outflow has not sufficed to drain. In that State

alone, one million eight hundred thousand gallons are said to be brought daily to the surface; and although the various oil companies have storage for at least five million barrels, of forty gallons each, these often prove insufficient for the quantity of oil raised. In these circumstances the material runs to waste, and it was lately computed that from want of sufficient storage three hundred thousand gallons were thus lost daily in Pennsylvania. No wonder that in districts where such overflows occur, the streams should become literally rivers of oil, or that occasionally sparks from passing locomotives should set them ablaze. There are nearly twelve thousand wells in operation in Pennsylvania, the produce of which is conveyed to the iron tanks and refineries by means of three thousand miles of pipe. The bore-holes by means of which the petroleum is worked are usually from three to four inches in diameter, and from five hundred to eight hundred feet deep, although oil is often found much nearer the surface.

When first "struck," the oil generally rises to the surface and overflows; while occasionally it issues with such force as to reach a height of forty to fifty feet above the ground. The discharge in the latter case is often very great, a single well of this kind having been known to yield twenty-five thousand barrels of oil in the course of a single day. This outburst, however, soon ceases, and the oil can then



OIL WELL, PENNSYLVANIA.

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only be got by pumping, by means of which a tolerably regular supply may be obtained for several years. One of the earliest borings at Oil Creek, and that which led to the rush of oil-seekers, tapped a reservoir which yielded twenty-five barrels daily; but this was altogether distanced by subsequent borings, many of which have yielded from three hundred to five hundred barrels a day for long periods.

A comparatively small quantity of the oil is exported in the crude state, the great bulk of it being refined in the neighbourhood of the wells. For this purpose it is placed in iron retorts and heated, when the naphtha is distilled over first, then the illuminating oil, and finally the heavy lubricating material. Wells similar to those of Pennsylvania are worked in Canada, and these are said to yield annually about eight million gallons of oil. It is not an unusual device of the Canadian, when, after making a deep rock-boring, he does not "strike oil," to explode an earthquake shell in the bore-hole, and by thus shattering the surrounding rocks, letting in whatever oil may be confined in adjacent fissures.

The abundance of the raw material, and the ease with which it can be refined, enable the American producer to sell his petroleum at a few cents per gallon. It is not surprising, therefore, that he should have found a ready market in all quarters of the globe for this brightest and cheapest of illuminating oils. The trade in it has assumed gigantic propor-

tions—petroleum, as an article of American export, ranking next in importance after cotton and food stuffs, its money value being stated at over sixty million dollars. Great Britain alone buys upwards of forty million gallons of the refined oil, in addition to a considerable quantity of the crude material; while the Continental nations are still better customers.

Having regard to the advantage which the American producer possesses in his oil wells, it might have been thought impossible for the British shale oil manufacturer to compete against such heavy odds; and this, no doubt, would have been the case had illuminating oil been the only marketable product obtainable from the shale. The home manufacturer, however, extracts solid paraffine from the crude oil, and sulphate of ammonia and other valuable chemical products from the waste materials of distillation; and it is to this utilization of waste substances that, in spite of American competition, the Oil Companies of Scotland owe their substantial dividends.

It is probable, however, that on the Continent, and especially in Germany and Russia, American petroleum will ere long have to compete with a native oil similarly obtained. The existence of rock oil in North Germany has long been known, and attempts have been made at various times to tap it. These, however, although confirming the fact of the presence of petroleum, have not been commercially successful. Renewed efforts were lately made in the

same region—about twenty miles from Hanover, near the small town of Peine—with the result that oil in quantity was " struck." " A spring," says a German correspondent of the *Builder*, " was intercepted of a yield and volume such as has not been exceeded even in Pennsylvania." When first " struck," the confined gas forced the oil out in a thick jet, and the lucky owner had considerable difficulty in obtaining barrels in which to store the unexpected supply. When the overflow ceased the pump was applied, and by this means it was made to yield twenty thousand imperial gallons daily, one-third of which was brine and the rest oil. Petroleum fever was inevitable after so striking a success, and several companies are now at work driving bore-holes, a few of which are already yielding oil ; although in these, it is said, the percentage of water mixed with the oil is very much greater than in the *spring well* already mentioned. It remains to be seen whether the petroleum wells of Oelheim, as the new township has been called, have tapped any very considerable subterranean store of this material.

Petroleum wells also exist in Galicia, and these, it is said, were drawn upon and the crude oil distilled and used for lighting purposes so early as the beginning of the present century. If this be the case, the honour of having discovered the illuminating powers of refined petroleum rests with Galicia. In one district of this Austrian province no less than four

hundred barrels of oil are obtained daily at the present time. Ozokerit, also, a mineral wax which yields about twenty-five per cent. of solid paraffine—shale oil yielding only two—occurs in considerable abundance in Galicia.

Rangoon, in Burmah, has long been famous for its petroleum wells; and before the discovery of rock oil in America, the product of those Asiatic springs was the rival of paraffine oils in our markets.

It is in the Russian empire, however, that the most productive oil wells of the Old World are found. The Americans have until lately outstripped the world in this matter. Single "gushers," that could in the course of twenty-four hours squirt a million gallons of crude petroleum to a height of sixty feet into the air, were supposed to be only possible in Pennsylvania. Recent events have, however, falsified the supposition, and our American cousins, if they would see the biggest oil fountains, must now travel to the Russian Caucasus. The facts regarding this region have been made public in a recent work by Mr. Charles Marvin.

In the region that lies between the Black Sea and the Caspian there are thousands of square miles of land more or less saturated with petroleum. In many places it exudes naturally from the ground, in others the soil has merely to be scratched in order to yield it, and the hill tribes have thus supplied themselves for centuries by digging shallow pits. The

oil-yielding rocks extend even beneath the Caspian, where their submarine course may be traced by the oil and gas which rise from them to the surface. The escape of gas in the sea near Baku is said to be sufficiently powerful at times to overturn boats, while the surface of the sea may be readily set on fire by the application of a light. The chief petroleum-yielding district is the peninsula of Apsheron, on which Baku stands. It has an area of about twelve hundred square miles, but as yet all the wells are crowded together on three of these.

Although it is only of late years that this district has risen into prominence as an oil-producer, it is known to have yielded petroleum for at least two thousand five hundred years, and to have had a commerce in it since before the discovery of America. A region that sweated petroleum and breathed petroleum gas could not fail to be specially attractive to the fire-worshippers of Persia, who here set up their altars six hundred years before the Christian era, and made it the "holy place" of the Zoroastrian worship. The "everlasting fires" then started were, it is said, maintained almost uninterruptedly till within the last few years. Marco Polo, writing in the thirteenth century, states that at Baku was "a fountain of great abundance, inasmuch as a hundred shiploads might be taken from it at one time. This oil is not good to use with food, but 'tis good to burn, and is also used to anoint camels that have the

mange. People come from vast distances to fetch it, for in all countries round there is no other oil."

The Russian Government, when early in the present century the oil region of the Caucasus was wrested by them from the Persians, threw away their opportunity of developing the petroleum industry by rendering the export of oil a State monopoly. Under this system the quantity of crude petroleum annually extracted slowly advanced from about three thousand tons early in the century to twenty-four thousand eight hundred tons in 1872. Meanwhile the Americans had struck oil, and had already flooded the markets of Europe with the product of their wells. This led the Russian Government in 1872 to abolish the monopoly on the Caucasian oil, an excise duty being imposed instead, with the result that at the end of five years the production of crude petroleum had increased tenfold. At the end of 1877 the excise duty was also removed and the trade left perfectly free; since which time the production has gone on increasing, no less than eight hundred thousand tons of crude petroleum having been taken out during 1883. It is only since the monopoly was abolished that the exceeding richness of the oil region of the Caucasus has been fully realized. Wherever wells have been sunk oil is invariably found, and generally at inconsiderable depths. There are now about four hundred of these wells in operation on the three square miles of

plateau which is all the petroleum ground yet "exploited." Although there is little doubt that the rest of the peninsula is equally rich in petroleum, there is a disinclination to bore for it beyond the plateau where success has hitherto been invariable, and which already supplies more of the crude material than can at present be profitably utilized.

Although the wells are thus necessarily very close to each other, it is not often that two of them are found to draw their oil supply from the same subterranean source. The ground underneath would seem to be honey-combed with huge cells, each forming a separate reservoir of oil; and if in boring the same cell should be twice tapped, it merely shows that a larger reservoir than usual has been reached. As a matter of fact, however, it is found that wells situated only a few yards apart yield oil at totally different depths, thus showing that they draw it from different sources. The owner of a Caucasian oil well need not therefore, as a rule, fear lest a neighbouring proprietor should draw off his oil by means of another boring. If there be no present demand for it he has simply to seal it up, in the full assurance that it will keep. In Pennsylvania, on the other hand, the soil is so disseminated in strata that the same supply may be tapped by wells considerably apart; consequently the American who first strikes oil must make all haste—if he would not have it shared by others—to bring the whole of it to the surface.

None of the wells in the Caucasus are more than eight hundred feet in depth, while the majority of them are probably less than half of that. The deeper the well, however, the greater as a rule is the supply of oil obtained from it. "Gushers," as the Americans call their oil fountains, are not unknown in the Apsheron peninsula. Marco Polo refers to them as occurring six hundred years ago. These seem, however, to have been insignificant compared with those which have occasionally followed the boring operations of the past ten years. There have been about fifty such oil fountains in play during that period, and several of these have exceeded in force, volume, and duration anything of the kind known in America. In 1875 one well spouted two thousand four hundred tons of oil daily, and formed in the course of a month four vast lakes of oil. In 1883 three such outbreaks occurred. One for the first three-quarters of an hour ejected sand to a height of between three hundred and four hundred feet. This was followed by a terrific blast of gas, which poisoned the atmosphere of the oil district for a whole day, and thereafter the oil rose in a huge jet to a height of two hundred feet. Another well belonging to Nobel Brothers—the Russian oil kings—spouted thirty million gallons to the surface; while a third—the great Droojba fountain—rose at intervals to a height of three hundred feet, and ejected oil at the rate of eight thousand tons a day. Un-

fortunately the latter belonged to a poor American company who had no means of storing the oil, so that hundreds of millions of gallons given out by the fountain before it could be plugged were not only lost, but they so overwhelmed neighbouring wells and works that the owners of the Droojba were at last driven into bankruptcy through the claims for compensation showered upon them. When oil is struck, its rise to the surface is usually preceded by a blast of carburetted hydrogen gas and the outrush of sand. This interval before the rush of oil is utilized by the workmen in removing the boring rod and in fastening an iron cap over the orifice, the latter being fitted with a sliding valve to regulate the flow of oil. When this is successfully accomplished, the nuisance of an irrepressible oil fountain is obviated.

That there is no lack of crude petroleum is shown by the fact that of the forty wells owned by Nobel Brothers, no fewer than fourteen are plugged down as being at present unnecessary. The oil after leaving the wells flows into huge ponds, from which, after the sand in it has had time to settle, it is pumped into iron reservoirs, and from thence conveyed through iron pipes to the refineries at Baku, a distance of about eight miles. Formerly all the oil was conveyed to Baku in rude carts. Nobel Brothers, however, introduced pipe lines for this purpose, and now there are about sixty miles of piping

laid between the wells and the refineries. Baku, from being a miserable village, has grown through the petroleum industry to a large and flourishing town, one of its oil refineries being the largest in the world, while the extent of its trade may be judged from the fact that seven thousand ships enter its port and leave every year. The production of kerosine, or burning oil, is the chief aim of the Baku refining establishments; but unfortunately the crude petroleum of the Caucasus is poor in this constituent as compared with that of Pennsylvania. From the latter fully seventy per cent. of kerosine can be obtained, while the Russian oil only yields twenty-seven per cent. This is somewhat compensated for by the much greater quantity and better quality of the lubricating oil obtained from the latter. It must also be remembered that the Russian crude oil is much cheaper than the American, being at present only threepence halfpenny per ton.

Before the advent of Nobel Brothers on the Caucasian oil region, defective refining machinery and the expense of conveying the refined oil into the European markets gave the American oil an easy victory over that of Baku, even in Russia itself. Those enterprising Swedes—one of whom invented dynamite, while their father invented the torpedo—have changed all this. They have reduced working expenses by having the crude oil conveyed to Baku in pipes. Their refinery, with its forty-two retorts

constantly at work, produces a burning oil at least equal to the best American. They introduced cistern steamers for the cheap and rapid conveyance of the kerosine to the mouth of the Volga, and there is now a fleet of fifty of those liquid transports constantly passing up and down the Caspian, propelled by engines using petroleum fuel. Arrived at the mouth of the Volga, the oil is transferred to a second flotilla of cistern steamers, suited for river navigation, by which it is conveyed to Tsaritzin, the first railway station on the Volga—the entire journey from Baku to this point being performed in about four days. At the principal railway stations throughout Russia, Nobel Brothers have established immense depôts for the storage of their oil; and to these, as occasion requires, they run trains composed entirely of tank cars, in which the oil is conveyed without the expense and trouble of putting it in barrels. There are sixty of these oil trains constantly moving to and fro throughout Russia, the oil being sold at the depôts to dealers, who bring their own barrels. In this way Nobel Brothers annually dispose of fifty-four million gallons of kerosine, not a drop of which, it was recently stated, is sold except for ready cash. The result of all this energy, foresight, and science is, that the best burning oil, which at Baku costs only a penny a gallon, can now be sold throughout the Russian Empire at a figure so low that America can no longer compete with it.

A German company has lately been formed for distributing Baku kerosine over the German Empire, and arrangements were lately being made for establishing depôts and running oil trains over the German railways. Nobel's kerosine has also been introduced into Austria, where it has succeeded in under-selling the American article. It is proposed to run cistern steamers from Libau on the Baltic to French and English ports; also to pour oil into the Mediterranean countries, and through the Suez Canal into India, by means of similar steamers from Batoum on the Black Sea. The latter port has been connected with Baku by railway since June (1884); and from then to the end of the year nearly three and a half million gallons of oil were conveyed to Batoum for shipment abroad. The Russian oil industry is yet in its infancy, for the other products of crude petroleum—benzin, lubricating oil, and liquid fuel—are only beginning to be utilized. With Baku readily accessible by steam communication, its petroleum products ought soon to do more than hold their own in all the European markets.

XV.

RECENT GEOLOGICAL THEORIES.

SCIENTIFIC theories necessarily lack finality. Sufficient to-day to explain all the known facts, to-morrow's discoveries may show their inadequacy, and lead to their modification or abandonment. In the young and growing science of geology, examples of this are not of infrequent occurrence; and attention may here be directed to two instances, at present attracting notice, in which the preconceived ideas of geologists will probably have to be modified in accordance with the facts now known.

There is probably sufficient evidence to justify the statement that every spot which is now dry land has at some former period been sea, and that once and again during the geological ages such alternations of sea and land have taken place. To effect those changes nothing more is needed than time and the operation of such forces as are now at work. Rain, frost, and the other aerial agencies, are slowly but surely rubbing down the present

land surface, and carrying the detritus to the sea, where it goes to build up future continents. Thus the whole of Europe, it has been calculated, would, at the present rate of denudation, be reduced to the level of the sea in three and a half million years.

Meanwhile the silent elevating forces are raising a new earth inch by inch out of the ocean, as is seen in the case of the Baltic shores, which are rising out of the water at the rate of four feet in a century, and still more along the western coast of South America. The position and configuration of the land surface is thus constantly if slowly changing; and Sir Charles Lyell, noting how the dry land thus shifted about in the sea, concluded—and his view has until lately been generally accepted—that no limit could be set to its peregrinations. "It is," he says, "not too much to say that every part of the space now covered by the deepest ocean has been land." And on this assumption he based important conclusions regarding geological climate.

Recent investigations, especially with regard to the deep sea, have convinced our leading geologists that the theory that the abyssal ocean floors have been land must now be discarded. The deep-sea soundings of the *Challenger* and other exploring vessels have proved the sea-floor to consist of enormous areas of depression—the ocean basins—thousands of feet below the level of the land, and forming vast submarine plains not unlike the sub-

aerial prairies and pampas of America; also of much shallower areas, usually bordering on existing lands, and which, as Dr. Carpenter suggests, may be regarded as submerged portions of the adjacent land-platforms.

These two areas do not merge gradually into one another as the land surface and the shallow-water area may be said to do, but are so abruptly defined that from a depth of one hundred fathoms on the edge of the submerged platform the sounding-line suddenly descends to nearly fifteen hundred fathoms on the true ocean-bed. It is on the shallow-water area that the sediment derived from the waste of existing lands—the raw material of future continents—is being deposited, none of it being carried so far as to reach the abyssal sea; and Dr. A. Geikie and others maintain that a study of the aqueous rock formations of the globe shows that these have been deposited in shallow waters, just as they are at the present day. The sedimentary rocks of the older formations, thousands of feet in thickness, bear evidence, in their oft-recurring ripple-marked surfaces and in their annelid tracks, that they have been deposited on or near the shores of existing land. That they should have attained such thickness, and still retained throughout their shallow-water aspect, is only explicable on the supposition that as they were deposited the area of deposition gradually sank. The stratified rocks of

the globe consist for the most part of sandstone, shale, and conglomerate, all manifestly the *débris* of former lands; and similar material is still being constantly carried down by rivers and deposited in modern seas. The coarser material naturally falls to the bottom first, while the finest particles are carried furthest out. The *Challenger* dredgings, however, showed that even the finest mud is rarely deposited at a greater distance than two hundred miles from the shore. It is within this shallow-water area that there is reason to believe all the rocks derived from the waste of continents have been formed.

The Chalk formation has been regarded by many as a true oceanic deposit, and the cliffs of Dover and the wide area of chalk land have been pointed to as proving the non-permanence of ocean basins. Advocates of this view rely greatly on the fact that at the present day there is being deposited over a considerable area of the Atlantic Ocean, at depths ranging from two hundred and fifty to nearly three thousand fathoms, a white ooze which they regard as exactly corresponding to the chalk of Cretaceous times. This theory has lately been combated by Mr. A. R. Wallace, who shows that these ancient and modern white muds differ so considerably in composition as to favour the view that they have to some extent a different origin. The great excess of carbonate of lime, and the small quantity of silica

in true chalk as compared with globigerina ooze, may be best explained on the supposition that true chalk is largely the result of the decomposition and denudation of ancient coral reefs. It is an important fact, also, that all the shells found in the chalk have been declared by our best authority on the subject to be without exception comparatively shallow-water forms. These and other facts adduced by Wallace go far to discountenance the view that oceanic conditions prevailed in Europe during the Cretaceous period. It is, however, says the above writer, "quite consistent with the existence of a great Mediterranean Sea of considerable depth in the central portions, and occupying either at one or at successive periods the whole area of the Cretaceous formation."

Sir Wyville Thomson found that beds of sediment were being slowly formed on the deepest ocean floors, consisting almost entirely of disintegrated volcanic matter; but he also found that those deposits could not be said to correspond either in composition or structure with any known sedimentary rocks. So slow, however, is the rate of deposition in the ocean depths, that it has been compared to the fall of dust in an unoccupied room. No better proof of this could be found than the fact that an examination of the abyssal mud disclosed the presence of an appreciable proportion of meteoric iron—the product of those falling stars which

dissipate themselves on entering our atmosphere. "To be told," says Dr. A. Geikie in a recent lecture, "that mud gathers on the floor of those abysses at an extremely slow rate conveys but a vague notion of the tardiness of the process; but to learn that it gathers so slowly that the very star-dust... forms an appreciable part of it, brings home to us, as hardly anything else could do, the idea of undisturbed and excessively slow accumulation."

These and other facts, such as the enormous disproportion between the mass of land above sea-level and the volume of ocean water—the latter being thirty-six times that of the former—are those mainly relied on to prove that both the present continental ridges and the marine abysses have existed in some form or other from the remotest geological times, their existence being probably due to the contraction of the Earth's crust, consequent on its gradual cooling. Around those ridges the land surface is now believed to have been more or less aggregated at all times, while those alternations of sea and land which Lyell supposed to have been coextensive with the globe, are now, on this theory, confined to the limits of the shallower areas of the ocean.

Few theories have won their way more legitimately to the position of recognized scientific doctrines than that which seeks to explain all past geological phenomena by a reference to causes now in operation. The doctrine of uniformity may,

however, be too literally interpreted. It is quite possible that certain agencies may have been more potent at particular epochs than they are now, and that these may not always have manifested themselves in exactly their present fashion. Such a view is suggested by a perusal of Dr. A. Geikie's remarkable paper on "The Lava Fields of North-Western Europe." In our minds volcanoes and lava are inseparably associated with cones and craters. Vesuvius and Etna rise before us as types of the vents by which at the present day the molten contents of subterranean lakes are poured upon the surface; and the doctrine of uniformity suggests that from similar craters all the basalts and other ancient lavas which testify to volcanic activity in former geological periods have been ejected. That "cone and crater" have probably been the most frequent type of volcano, Dr. Geikie is prepared to allow. He regards it, however, as less portentous, and as belonging "perhaps to a feebler or waning degree of volcanic excitement," as compared with another form not represented at the present day, but a splendid illustration of which, he believes, is to be seen in the basalt plateau of north-western Europe. There is abundant evidence that during Miocene times an area stretching from Britain in a north-west direction to Iceland was the scene of enormous volcanic energy, manifesting itself in the outpouring of floods of lava, which spread far and

wide to a great depth and in nearly level sheets, and in which "the hills of Antrim, Mull, Morven, Skye, Faroe, and part of Iceland are merely fragments." Dr. Geikie has further satisfied himself that those most remarkable features of ancient volcanism in this country, the basalt *dykes*, which can be traced from Yorkshire to Orkney, and from Donegal to the mouth of the Tay, and which grow more numerous as the basaltic plateaus of Antrim and the Inner Hebrides are approached, belong to the same volcanic period, and are, indeed, parts of the same outburst.

If these ancient lavas had an origin similar to those of modern times, where are the vents by which when in a molten state they were poured forth? Denudation might have obscured or even removed them, but not without leaving traces of thickening in the basalt towards the point of eruption. No such traces have ever been found, while the remarkable horizontality of the basalt beds, and the presence of those huge fissures filled with basalt, and extending in some cases two hundred miles from the central lava fields, have absolutely no light thrown upon them by the study of the "cone and crater" type of volcano.

It was while viewing the lava fields of the Pacific Slope, and especially the Great Snake River lava desert of Idaho, that the probable explanation of the Miocene basalts of his own country dawned upon

Dr. Geikie. Geologically speaking, those American lavas which extend over vast plains in horizontal sheets are quite recent, looking, indeed, as if they had just had time to cool; but there is no known crater from which they can have been poured. There are fissures, however, all round; and that these are still more abundant beneath the lava-floor Dr. Geikie does not doubt. He therefore accepts the theory propounded twelve years ago by Richthofen, but at that time rejected, of "massive eruptions;" that is, of the emission of lava through fissures, the lava having "welled forth so as to flood the lower ground with successive horizontal sheets of basalt." What has thus happened in comparatively recent times in the wondrous volcanic regions of the "Far West," Dr. Geikie believes to have happened in Miocene times in Britain, where it produced that "greatest of all the episodes in the volcanic history of Europe—that of the basalt plateaus of the North-West." In the absence of any explanation of the peculiar phenomena of Miocene volcanism on the "cone and crater" theory of volcanic action, geologists will accept that of "massive eruptions" all the more readily that it has been adopted by Dr. Geikie after a profound study of the subject in several of the best volcanic fields in the world.

XVI.

A NEW THEORY OF THE ORIGIN OF CORAL ISLANDS.

FEW objects are more beautiful or more interesting than the coral islands of tropical seas. Built up of lime extracted from the surrounding waters, by countless myriads of the humblest organisms, they are as sea-born as ocean shells. The sea, which everywhere else is the destroyer of land, acts in a totally opposite fashion on these products of itself. The more its waves beat upon the barrier of live coral, the more the latter grows, for these bear with them the food on which the polyps live. Occasionally masses both of living and dead coral are broken off by the force of the waves; but even this apparent destruction would seem to be essential to the formation of a coral island. The coral animals cannot live above water even for the short interval between tides; their upward growth, therefore, ceases just before they reach low-water level, and coral plantations would consequently remain submarine were it

not for the action of the sea in throwing upon the surface masses of coral torn from the sides during storms. These, by the dissolving action of the carbonic acid in sea water, get cemented to the surface, forming coral rock; and by such means the structure is gradually reared above the waters. Seeds carried by birds or by ocean currents get thrown on the new-formed island, its surface becomes diversified with luxuriant groves, birds find their way to it, and, last of all, man takes possession. Navigators have occasionally come upon isolated coral islands without human inhabitants, in which the birds were so innocently fearless that they allowed themselves to be picked from the trees like fruits; and others in which the inhabitants had so utterly forgotten their original home as to be without knowledge of any other land or people. Their sea-girt island, "without rivers, without hills, in the midst of salt water, with the most elevated point but ten to twenty feet above high water, and no part more than three hundred yards from the ocean," formed their world.

One of the most striking peculiarities of coral islands is their shape. They form vast rings of dry land, with the ocean on the outside and a lagoon of salt water, generally connected with the sea by one or more openings, on the inside. How it came about that so many thousands of islands in the Pacific and Indian Oceans assumed this *atoll* form,

as it is called, remained a mystery until fully forty years ago, when Darwin, after a profound study of the subject, made while sailing among those islands in the capacity of naturalist on board the *Beagle,* propounded a theory of their origin, the immediate acceptance of which by the scientific world contrasts remarkably with the reception at first accorded to his later and more famous theory.

It ought here to be stated that while the coral polyps cannot live out of water, neither can they live—at least those of them which form reefs—at a greater depth in the water than from twenty to thirty fathoms. Coral islands, however, in most cases rise out of the ocean at enormous depths; any theory to be satisfactory must, therefore, not only account for the ring-like form of those structures, but must also explain how their builders obtained a basis at the proper depth for their operations.

According to Darwin's theory, each of these *atolls* at one time formed a reef closely surrounding an island, but the sea bottom having begun to subside, the island gradually sank. The foundations of the coral edifice descended with it; but so gradual was the subsidence that the polyp had time to build upward so as to keep its stony structure on a level with the surface. This process of subsidence in the island and of growth in the coral went on concomitantly, until the island finally disappeared beneath the waves, and the initial fringing reef became a

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ring of land enclosing a lagoon. In confirmation of this theory, examples illustrating all the intermediate stages from fringing reef to atoll were shown to exist at the present day. Thus, the lofty island of Tahiti is simply encircled with a shore reef, while in Gambier's group only a few peaks remain to mark where, according to this theory, an island whose outline is roughly indicated by the form of the surrounding barrier reef once stood. In thus calling subsidence to his aid, Darwin did not invoke a new and hitherto unknown geological agent. Oscillations of the Earth's surface have been of frequent occurrence in recent geological time, and certain coasts, such as those of Greenland, are known at the present day to be subsiding, whilst others are rising.

Darwin's theory was so manifestly superior to any which preceded it in explaining all the known facts through the action of recognized agents, that it met with ready acceptance. The labours of Dana and others in the same field tended still further to confirm it, and it is only now that its claim to be regarded as the true theory has been seriously questioned. In a recent paper, Mr. Murray, one of the naturalists on board the *Challenger*, propounds, as the result of his investigations of those islands and of the sea-bottom generally, a new theory of the origin of coral islands and reefs. This he was led to seek through the difficulty he

found in applying Darwin's theory in the coral reef regions visited by the *Challenger*. He rejects the subsidence theory as unnecessary, and plants his coral islands, not on sinking land, but on submarine volcanoes and other sub-aqueous elevations produced by the disintegration of volcanic islands. Darwin recognized this as an alternative theory, but rejected it on the ground that it made it necessary to assume the existence of an incredible number of lofty submarine mountains, all rising to within twenty or thirty fathoms of the surface—a uniformity in height altogether unknown in the peaks of any subaerial mountain chain.

Fifty years ago, however, comparatively little was known of the sea bottom, much that is now known of it being the result of the *Challenger* soundings. Those deep-sea researches have made known numerous submarine mountains rising from fifteen thousand to eighteen thousand feet above the bottom of the sea, and reaching within a few hundred fathoms of the surface. It is evident, however, that a coral polyp could no more exist at the summit of those elevations than it could at their base three thousand fathoms below, and the most original feature in the new theory is the method by which, it is alleged, those gigantic pedestals are raised to the height necessary for the commencement of coral building operations. Marine life is shown to be abundant in the surface waters of the ocean, and to a depth

of about a hundred fathoms, while the shells in which much of that life is contained have an amount of lime in them sufficient to justify the conclusion that there are sixteen tons of it in this form present "in a mass of the ocean one mile square by one hundred fathoms." Much of this gets dissolved by the carbonic acid contained in sea water before reaching the bottom at great depths; this does not happen, however, when it falls on those submarine elevations near the surface. It accumulates there, and meanwhile these heights become the abode of all sorts of marine creatures, who live and die upon them, and the mineral constituents of whose bodies go to raise the summit, until in process of time they prepare a place for the coral polyp. The latter having thus obtained a footing, rears its stony edifice until it reaches the surface, where, strange to say, it is seen to have the characteristic ring-like form of the atoll with its enclosed lagoon. This it owes to the fact that it has grown more vigorously around the margin than on the central expanse, where its growth is checked by the deposition of sediment and by the smaller amount of food which reaches it.

According to the new theory, barrier reefs surrounding islands or skirting the coasts of continents have been built out from the shore on a foundation of dead coral and other *débris* which has given them the necessary elevation, the navigable channel

between the shore and the reef having been produced in the same way as the lagoon of the atoll—namely, by the insufficient nourishment of the coral, and its consequent decay and removal. There seems little doubt that coral islands raised on submarine mountain-tops would thus assume the atoll form, and Darwin admitted that such would be the case. His theory of subsidence was not therefore invoked in order to explain the atoll form, but rather to supply a basis on which the coral animal could build. The pedestal theory was rejected by Darwin for what at the time were considered valid reasons.

Recent research has, however, deprived these reasons of much of their force, while it has raised hitherto unsuspected difficulties in the way of accepting Mr. Darwin's theory. If, for example, the coral islands of the Pacific and Indian Oceans are monuments raised on the peaks of a sinking continent, how is it that there is no trace of continental rocks in the oceanic islands of these regions? These are purely volcanic, and without trace of the granites and schists that bulk so largely in the peaks of continental mountain-chains. That a subsidence such as Darwin postulates would have given rise to conditions necessary for the growth of coral reefs and atolls is undoubted, but so also would submarine volcanic peaks and plateaus. Of subsidence, however, at the present day in the region of coral islands there is no proof; on the contrary, there are many

indications of upheaval. Submarine volcanic peaks and plateaus, on the other hand, do exist. Some of these may at one time have risen above the water, but by the eroding action of the waves they may have been worn down to the depth at which coral growth becomes possible. Others may have fallen considerably short of the height necessary to bring them within the coral zone; but they may have reached the necessary elevation by the gradual accumulation of dead shells and other organic remains on their surface. That such remains are at the present day forming sheets of limestone on the floors of submarine banks in the warm seas where coral flourishes, was recently shown by Professor Alexander Agassiz. "No one," he says, "who has not dredged near the hundred-fathom line on the west coast of the great Florida plateau can form any idea of the amount of animal life which can be sustained upon a small area under suitable conditions of existence. It was no uncommon thing for us to bring up in the trawl or dredge large fragments of the modern limestone, now in process of formation, consisting of the dead carcasses of the very species now living on the top of the recent limestone." The coral reefs of the Florida coast afford a splendid field for the study of this subject, and these have been examined minutely by Professor Agassiz, whose conclusions corroborate generally those arrived at by Mr. Murray.

XVII.

UPS AND DOWNS OF THE LAND SURFACE.

Oscillation of the Earth's crust is naturally associated with regions of volcanic energy. That the island of Krakatoa, seven miles long and five broad, should have suddenly disappeared amid a volcanic outburst, and that the entire physical geography of the Sunda Strait should have been altered in a day, is only what might be expected at greater or less intervals in such a home of seismic energy. Similar events have occurred in other volcanic centres. Exactly a century ago an island arose on the west coast of Iceland, only to disappear again in the course of a year. Fifty years later, Graham's Island, between Sicily and Africa, rose out of the waters amid showers of scoriæ and clouds of steam; but after attaining a circumference of three miles, and an elevation of two hundred feet, it gradually disappeared beneath the waves. A still more remarkable case was the appearance above the water

of an island off the coast of Alaska, which in four years developed into a volcanic cone three thousand feet above sea-level.

Movements such as these attract attention by their suddenness, and by the terrible grandeur of the phenomena accompanying them. It is not to be supposed, however, that because other parts of the Earth's surface are not subject to earthquake spasms that they are therefore free from all oscillatory movements. On the contrary, over wide areas of the present land surface elevation is taking place, while in other regions subsidence is equally marked; yet such movements, whether upward or downward, are so gradual as to be almost imperceptible in a lifetime, although the changes thus effected are incomparably greater than those wrought by the violent but comparatively local action of earthquake and volcano. It is but as yesterday, geologically speaking—for it comes within the human period—since Great Britain, and probably a large part of the Continent, gradually sank beneath the waves. Scotland and Wales then became a cluster of islands, only mountains exceeding two thousand feet in height being above water; and it was on the flanks of the latter that those marine mollusks probably lived whose shells are now found on the Welsh hills fourteen hundred feet above the sea. The emergence of Britain from the water marked the close of the great Ice age, and was probably as gradual a process as its previous submergence had been.

Movements of a similarly silent and uniform character are known to be taking place at the present day. Thus there is evidence that the west coast of Greenland is sinking at the rate of from six to eight feet per century. Ancient buildings are there seen to have been covered by the sea, and the Moravian settlers have more than once had to shift their boat poles further inland. A similar subsidence is taking place in the south of Sweden, where streets originally above high-water mark are now below it, and where Linnæus noted the position of a stone in 1749 which in 1836 was found to be a hundred yards nearer the edge of the water. While Greenland is sinking, there is ample evidence that Norway, Spitzbergen, Labrador, Hudson's Bay, the shores of Behring Strait, and the east coast of Siberia are rising. At Spitzbergen, small islands which existed as such two hundred years ago are now joined to larger ones; while the Nova Zembla coast shows a rise of fully a hundred feet since the Dutch expedition of 1594. The shores of Hudson's Bay, it was recently estimated, have thus risen from five to ten feet within the century. A similar gradual rise has also taken place in recent times along the west coast of South America.

Our own shores afford abundant evidence in their raised beaches of the recent elevation of the land. Along the shores of the Firth of Forth shells are found embedded in the clay above high-water mark

GRAHAM'S ISLAND IN AUGUST 1831.

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in the exact position in which they lived and died, yet these shell-fish now-a-days can only exist at or under low-water level. Their present position, therefore, indicates a former low-water mark, and proves a rise of at least eighteen feet in the land since those mollusks lived. So, also, in many parts of the west coast, as in the island of Arran, the sea formerly beat upon a line of rocky cliffs; but the land has since risen, and now between the cliffs, overgrown with the most luxuriant vegetation, and the sea, which formerly excavated the caves at their base, there runs a road, and it may be a field of corn, or the potato patch of a crofter. Sometimes a succession of these beaches occur one above the other to a height of a hundred feet, while along the Norwegian fiords they rise in successive terraces to a height of six hundred feet, each terrace marking a former-sea level.

While the successive terraces or raised beaches on the Scottish and Scandinavian coasts prove that the land has risen time after time, the numerous firths or fiords and sea-lochs of the same coasts are themselves evidence of a former subsidence. No one, says Dr. A. Geikie, can attentively compare the maps of the land with the charts of the sea-bottom in that region "without being convinced that the endless ramifying sea-lochs and fiords, kyles and sounds were once land valleys. Each loch and fiord is the submerged part of a valley, of which we still see the

upper portion above water; and the sunken rocks and skerries, islets and islands, are all so many relics of the uneven surface of the old land before its submergence. The indented form of the coast-line of the west of Scotland and of Norway is not evidence of the unequal encroachment of the sea, as is often, perhaps generally, supposed, but is due to a general submergence of the west side of the two countries, whereby the tides have been sent far inland, filling from side to side ancient valleys and lakes."

Throughout the geological ages these slow movements of the Earth's crust appear to have been taking place. Our knowledge of these ages is derived from a study of the sedimentary rocks deposited at the different periods, and geologists are now generally agreed that those sediments have for the most part been deposited in shallow water. If this be so, there must have been a gradual sinking of the area in which the sedimentary strata accumulated, in order to make room for the enormous development they often attained. Thus the coal measures in South Wales have a thickness of ten thousand feet, and the Cambrian deposits of twenty-three thousand feet.

It is much easier to prove the occurrence of secular upheaval and depression than to give the causes of those terrestrial oscillations. Hitherto the favourite theory has been the one which ascribes all such movements to contraction of the globe, due to its

gradual loss of heat through radiation. It has thus been shown that since the globe was in a molten state it must have lost a hundred and eighty-nine miles of its diameter by contraction. This would cause portions of the outer crust to subside upon the hotter nucleus—a subsidence which could not fail to produce a bulging out of some other portion of the crust, and thus bring about more or less upheaval. Under the old view of the internal fluidity of the Earth this theory fairly met the requirements of the case; but now that physicists maintain that the interior of the globe must be solid, with a rigidity of the whole sphere equal to that of glass or steel, the favourite theory has become to some extent discredited. What is now regarded by many geologists in this country, and still more in America, as a more satisfactory explanation of the facts is the theory lately brought into prominence by Mr. Starkie Gardner, according to which the solid crust of the Earth subsides or rises in proportion as mineral matter is deposited upon, or removed from its surface. This theory requires the existence of a viscous layer between the solid crust of the Earth and its equally solid interior, without which it would be impossible for the Earth's surface to bob up and down according as weight was added to or taken from it. In favour of this theory there is the undoubted fact that sedimentary strata have in all ages been deposited in areas of subsidence, and that in those areas

subsidence and sedimentation seem for the most part to have kept pace with each other. The great rivers of the world—the Nile, Mississippi, and Ganges—have carried down in their waters solid material the removal of which from the land surface has given origin to deep valleys of enormous extent. Deposited at their mouths, this material must long ago have converted vast tracts of the sea into alluvial plains, had not subsidence kept almost equal pace with the sedimentary accumulation. Borings in the deltas of these rivers prove that such subsidence has taken place by the great thickness of the alluvial deposit, every layer of which represents a former surface. Soundings have shown that coral reefs and islands may rise from depths of over one thousand fathoms; corals, however, cannot live at greater depths than fifteen to twenty fathoms. Darwin accordingly concluded that the sea-bottom over a wide area of the Pacific has been gradually sinking, at least from the depth at which the coral lives, and that the growth of the coral has thus kept pace with the subsidence. According to the theory advocated by Gardner, Fisher, and others, the subsidence in this instance is due to the increased pressure caused by the enormous weight of coral accumulating on those islands and reefs.

The submergence of our country and most of Europe during the Ice age is, on the same theory, the result of the enormous accumulation of ice—six thousand feet thick in Norway—pressing on its

THINGVALLIR, ICELAND.

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surface; and this view is distinctly favoured by the fact that the rise of the land was coincident with the removal of the ice-cap. The overwhelming of reindeer pastures by the ice in Greenland since the time of the Danish occupation would seem to prove that ice in Greenland is increasing; and as its west coast is known to be sinking, the growing weight of ice may be the cause, of which the observed subsidence is the effect. If vast accumulations of material on the Earth's surface cause subsidence, it might be supposed that great outpourings of lava would have a distinctly depressing influence. Mr. Gardner has studied this branch of his subject in Iceland, and has given some remarkable instances of depression having followed the deposition of immense lava outflows. Thus a great lava flow has, he states, debouched at some period from three visible craters on to the historic plain of Thingvállir, forty square miles of which is water. "At its northern end the lava is still in its original position upon the slopes, but the whole central mass in the plain has torn itself away from the sides and sunk a hundred feet, leaving vertical cliffs of solid lava of that height on its flanks." Similarly, near My Vatn there is an immense tract of lava which was added to in 1875 by an outflow estimated at thirty-one thousand million cubic feet. Here also the centre of the flow is seen to have broken away from its flanks and sunk, Lake My Vatn having, as Mr. Gardner

believes, been formed by the weight of lavas which have poured on to the plain from nearly every side.

It is hard to believe that this solid Earth can be so sensitive to changes in the distribution of weight on its surface, that the accumulation of sand, mud, or lava to the thickness of even a few thousand feet could have a disturbing effect on the equilibrium of its crust. It ought to be remembered, however, as Mr. Gardner points out, that "however insignificant, some cause must initiate movement in the Earth's crust; and as an incautious shout may bring down an avalanche, so even an accumulation of a few feet of clay over several square miles may create a disturbing readjustment, and eventually lead to a downward tendency."

XVIII.

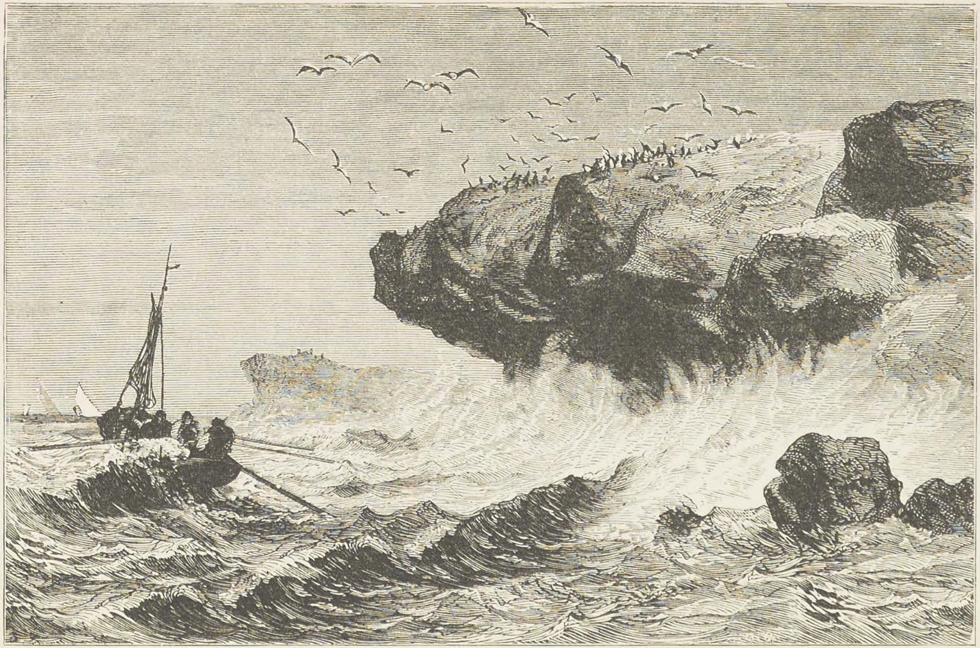
THE GEOLOGY OF THE SEA FLOOR.

ALTHOUGH man has not yet found the means of making himself at home on the bottom of the sea—a thing which Dr. W. B. Richardson anticipates will yet be done—he has, by the employment of such means of investigation as are at present available to air-breathing creatures, learned a great deal regarding the surface geology of the sea floor. Although he cannot walk along the subaqueous highway which stretches from Britain to America, and which has its telegraph wires like any subaërial road, he can tell much of the ups and downs of the way, and of the nature of the ground over which Dr. Richardson's traveller will have to pass.

The geological conditions prevalent on dry land are widely different from those that obtain on the bed of the sea. The surface of the former is being slowly worn away by a variety of denuding agents, while that of the latter is being gradually added to by an almost incessant shower of solid matter. The

material which forms this submarine rain differs in different areas of the ocean, and a knowledge of its composition supplies the key to the geology of the sea-floor. The most abundant material is that derived from the erosion of the land. After heavy rains in the British Islands the sea around these shores is made turbid by the mud washed from the land and carried down to it by the rivers. A like cause discolours the water at the mouth of the Amazon for three hundred miles seaward. Waves and tides beating on the coast are gradually wasting away the land margin, and, with the aid of currents, are distributing the *débris* over the adjacent sea-floor. The coarser material brought down by rivers, or removed by marine denudation, is the first to fall to the bottom, where it forms shore deposits of shingle, gravel, and sand. The finer material may be carried two or three hundred miles out to sea before the finest of its particles have settled on the bottom. Beyond this distance, however, it is now believed that whatever deposition takes place on the ocean bed is altogether independent of the erosion of the land surface.

As being mainly composed of the waste of existing continents, the deposits at present forming within two hundred miles of the coast have a distinct and recognizable character. So distinct, indeed, are they that during the *Challenger* voyage the approach to land could always be foretold by



SHOWING ACTION OF WAVES ON ROCKS.

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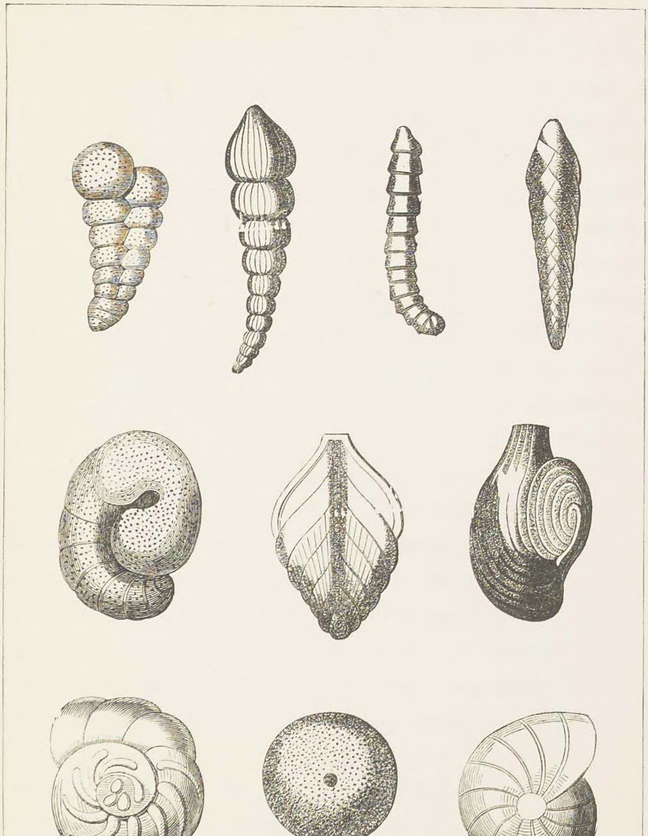
the character of the sediment brought up from the bottom. What these land-derived sea sediments are in appearance and in composition has lately been told in an important paper communicated to the Royal Society of Edinburgh by Mr. J. Murray and M. Renard. They are for the most part *muds*, coloured blue, green, or red; and when examined under the microscope are seen to be composed mainly of finely comminuted particles of the minerals that go to form the rocks of neighbouring lands. *Blue mud* is said to be the most extensive deposit now forming around the great continents; its colour being probably due to the presence of organic matter in a state of decomposition. Where iron is present, as in the muds of the Brazilian coast, it imparts to them a reddish hue, while others are coloured green by the mineral *glauconite*.

These muds—the clays and shales of some future land surface—contain in greater or less abundance the remains of bottom-living and pelagic animals, and thus a record of the life that now exists in those seas is being preserved for future reference. In seas the sediments of which are derived from the erosion of volcanic islands, the muds and sands deposited bear ample evidence of the fact, while coral muds and sands are being deposited in the seas surrounding coral-islands. The region occupied by these land-derived formations extends, says Mr. Murray, "from high-water mark down, it may be,

to a depth of over four miles, and in a horizontal direction from sixty to perhaps three hundred miles seawards, and includes, in the view we take, all inland seas, such as the North Sea, Norwegian Sea, Mediterranean Sea, Red Sea, China Sea, Japan Sea, Caribbean Sea, and many others." These, however, form but a small part of that waste of waters which hides from view two-thirds of the Earth's surface. The remainder is abysmal in its depth, and its floor is also being more or less constantly added to by the deposit of solid although not land-derived material.

Over wide areas of the warmer regions of the ocean, and at depths not exceeding two thousand four hundred fathoms, there is being deposited an organic ooze formed almost entirely of the shells of foraminifera. These microscopic organisms live and die on the ocean surface in countless myriads; and their dead shells sink gradually to the bottom, where countless generations of them have gone to form a *chalk* deposit of unknown thickness. In the North Atlantic alone this foraminiferal ooze covers an area of thirteen hundred miles in length by several hundred miles in breadth.

With the calcareous shells of foraminifera are usually mingled other forms, as the shells of pteropods, the frustules of diatoms, and the skeletons of radiolarians. In particular areas these other constituents so predominate as to justify Mr. Murray



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in speaking of such deposits as *pteropod, diatom,* and *radiolarian* oozes—the last two differing from the others in being siliceous instead of calcareous. In addition to their organisms these deposits contain a purely inorganic residue. This is a reddish clay composed for the most part of minute particles of pumice and other volcanic products. It forms an unimportant constituent of the ooze formations; but over the deepest and largest areas of the present sea basins this *red clay* is almost the sole material that is being deposited. At depths greater than two thousand four hundred fathoms the calcareous and siliceous skeletons gradually become scarcer, until they finally disappear at depths exceeding three thousand fathoms. The living organisms are still as abundant as ever at the surface; but their dead shells no longer reach the bottom. When it is remembered that to reach that goal they have to sink through four or five miles of water, which recent investigations have shown to contain in a free state that solvent of lime, carbonic acid, it is not surprising that during their slow progress downwards they should get completely dissolved. The red-clay deposit consists partly of the material transported by floating ice, partly of the exceedingly fine terrestrial dust sometimes borne by winds for long distances over the sea, but chiefly of particles of pumice and other more or less decomposed volcanic products.

The discovery of the universal distribution of pumice over the deep-sea floor was one of the most surprising results of the *Challenger* dredgings. Often the dredge would bring up bushels of rounded water-worn pieces of it, from the smallest size to blocks a foot in diameter. The abundance of this material becomes less surprising, however, when it is remembered that volcanic vents are in most cases near the coast, and that their dust and ashes thus fall in immense quantities on the water, whence they float long distances off, until, water-logged, they at last sink to the bottom. During the recent eruption of Krakatoa, the Bay of Lampong in the Strait of Sunda was, according to Mr. Murray, blocked in a few hours by a vast accumulation of pumice. The floating bar of pumice-stones was nearly twenty miles in length, eleven hundred yards broad, and from three to four yards deep. "This moving elastic wall," he says, "rose and fell with the waves and tide, and was carried by currents thousands of miles from the point of eruption over the surface of the globe." The dust from an Icelandic volcano has been known to fall in such quantities in the north of Scotland as to destroy the crops; and if the recent extraordinary sunsets have been due to Krakatoan dust, the quantity of that material ejected must have been enormous. Some of the volcanic *detritus* covering the ocean floor may also be the result of submarine

outflows of lava and ashes of which little or nothing is known.

This purely volcanic deposit is not confined to the abysmal region of the ocean. It is of universal occurrence over the sea-floor; but the deposition of organic ooze and of the products of land denudation proceeds so much more rapidly as altogether to mask the volcanic element. It follows from this that in the great depths, where nothing else is being deposited, the red-clay formation must be proceeding at an exceedingly slow rate. Of this there are one or two striking evidences. The only remains of animals found in it are the hardest parts of vertebrate skeletons, such as the teeth of sharks and the ear bones of whales. These are found much more abundantly in the red clay than anywhere else on the sea floor. Thus at a depth of 2,350 fathoms, between Honolulu and Tahiti, the trawl brought up, among other things, two hundred and fifty sharks' teeth, without taking into account those less than half an inch in length. Some were very large, three of them measuring from two to two and a half inches across the base. In the same neighbourhood another haul of the apparatus brought up no fewer than fifteen hundred sharks' teeth, while a third contained over one hundred and fifty ear bones and other remains of whales, besides the usual abundance of sharks' teeth. There is no reason for supposing

that whales and sharks are commoner in those seas than elsewhere, but their remains in shallow water soon get covered over by other deposits, and are thus saved from the dredge. The red-clay deposit, on the other hand, is being formed so slowly that these remains go on accumulating, it may be for ages, before they get buried up, and hence their relative abundance. The great antiquity of specimens yet unburied on the deep-sea bottom is seen in the fact that some of the teeth dredged have been found to belong to extinct species.

Another proof of the exceeding slowness of deposit of the red clay is seen in the presence, in much larger proportion than in any other marine formation, of particles of meteoric iron. That these magnetic particles from the sea floor are of cosmic origin may now be regarded as fully established. The minute spherules attracted to a magnet placed among the *red-clay* deposit, reveal, when broken down in an agate mortar, a gray metallic malleable nucleus, which can be beaten out into a thin plate, and which, on being chemically tested, gives the reaction of native iron. The few spherules that do not yield this are shown by further test to contain cobalt and nickel, both of which occur in meteorites. The outer coating too consists, as it does in true meteorites, of black oxide of iron—a chemical change due in both cases to the combustion that takes place on their outer surface in their

passage through our atmosphere. If further proof were needed, it is to be found in the presence of little siliceous spherules in the *red clay*, which under the microscope show a structure and constitution identical with that of the *chondres*, so frequently present in meteorites, and never yet known in rocks of terrestrial origin. This cosmic dust has been found in Arctic snows, and is supposed to be falling constantly over our globe. The fact that it should be found in such comparative abundance in the red clays of the deepest parts of the ocean shows how little else is falling there.

As might be expected in a material formed mainly of decomposing lava, the red clay is rich in manganese and iron; and the presence of these substances gives rise to the formation of concretions around organic bodies and bits of pumice. These ferro-manganese nodules, enclosing fossils, remind one of the ironstone balls or nodules, generally containing a nucleus of fish or plant remains, found abundantly in the lower carboniferous shales of Midlothian. The latter, however, there is reason to believe, were formed in shallow lagoons, the water of which was strongly chalybeate, whereas the modern nodules occur most frequently and in greatest abundance in the deep deposits of the Central South Pacific, the floor of which is, according to Mr. Murray, more largely strewn than any other with volcanic *débris*. These manganese

concretions were occasionally taken up by the *Challenger* trawls in vast abundance—half a ton weight of them being sometimes obtained at a single haul. The majority of them were like marbles in form, and from one-fourth of an inch to one inch in diameter, although some were no less than four inches in diameter. Their nucleus consisted of some volcanic material or of small teeth of sharks or other fragment of bone.

In the formations going on around continents at the present day, made up of the material worn by wind and water from the land surface, it is easy to see the building up of rocks similar to those with which we are familiar in the geological series; but in much of the organic ooze, and still more in the red clay, we have formations that have no known analogies. This is another of the many evidences that have of late years been adduced in favour of the view "that the present Continental ridges"—to quote from Dr. A. Geikie—"have existed from the remotest times, and that the marine strata which constitute so large a portion of their mass have been accumulated, not as deep-water formations, but in comparatively shallow water along their flanks." At all events, the opposing theory, that once and again the present continents have been ocean beds, and *vice versa*, finds little countenance from the facts lately made known regarding deep-sea deposits.

XIX.

AN OLD LAND QUESTION.

THE ventilation of the rights and wrongs of the crofters has of late years familiarized the public mind with the land question in the north. It is not so generally known, however, that the Highlands possess another land question which for a generation past has been the subject of more or less bitter controversy among geologists—a question bearing on the geological structure of that region.

It need hardly be said that the geological structure of the Highlands has had a most profound influence on the character, history, and pursuits of its population. That the originally identical Celt of Ireland and of the Highlands should have developed, the one into the volatile Irishman and the other into the "dour" Highlander, has been with good reason attributed to the difference geologically of the two countries. That there is a comparatively pure Celtic population at all in the north end of our island is due to the same cause; for had the

Highland mountains not interposed a barrier to the progress of the Saxon invader, the whole island would have been overrun, and the weaker race long ago absorbed in the stronger. The absence of towns, the want of manufactures, the wretched agriculture, and the abounding poverty of the Highlands of Scotland, all find, more or less, an explanation in their unfortunate geological structure.

What is that structure which has affected so adversely the fortunes of the Gael? To find the "roof of the world" one must go to Tibet; the floor of the world, or at least a fragment of it, may be seen in the north-western extremity of the Scottish mainland. Nowhere else can one tread on more ancient rocks than those which now form the land surface of a considerable tract along the western shores of Sutherland and Ross. It is the Archæan or fundamental gneiss of Murchison—the platform on which all the stratified formations of this country rest.

Various opinions have been held as to the origin of these primitive rocks, some regarding them as the first crust which formed around our once molten globe, others as early sedimentary deposits which have been metamorphosed by heat and moisture into gnarled crystalline masses. If life existed in the world when those Archæan rocks were formed, no trace of it has yet been found in Scotland. Rocks supposed to be of similar age in Canada

have, however, yielded the *Eozoon Canadense*, believed by some to be a massive foraminifer, by others to be merely an inorganic mineral structure.

From this platform of gneiss in Ross and Sutherland there rise here and there, to a height of over three thousand feet, mountains of red sandstone, which in colour and form contrast strongly with the crumpled schists on the upturned edges of which they rest. These sandstones were at one time supposed to belong to the "Old Red" formation, but they are now generally regarded as the Scottish equivalents of the more ancient Cambrian rocks of Wales. As yet they have yielded no trace of life. Resting upon these sandstones are a series of quartzites and limestones, surmounted, to all appearance conformably, by another set of crystalline schists known as the Upper Gneiss. The latter is *the* rock of the Scottish Highlands, covering, as it does, an area of not less than sixteen thousand square miles. Over the greater part of this region the schists are in a highly plicated and crumpled condition, and the more this is the case the more crystalline are the schists found to be. "Over the Scottish Highlands," says Dr. A. Geikie, "the gneissose and schistose rocks have been tossed, as it were, by a long swell from the north-west into numerous wave-like plications that follow each other, fold after fold and curve after curve, from Cape Wrath to the Lowland border."

What is the age of this widespread crystalline schist, the presence of which may be regarded as the physical basis of Highland misfortune? It was formerly believed to belong equally with the underlying fundamental gneiss to the age of chaos, when as yet the world was uninhabited and uninhabitable by any form of life. The view of the Huttonian school, that gneiss and schist were not necessarily "primary rocks," but that they might belong to any geological period during which there had been sufficient subterranean movement and heat to metamorphose its sedimentary deposits, had not yet been generally accepted. Macculloch was the first to surmise that those Highland schists might, after all, be of later age than the dawn of life on the globe. He found in the quartz rocks beneath the schists curious tubular objects which he regarded as organic. The idea of fossils occurring beneath the so-called primary rocks was, however, so wildly improbable that even Murchison and Sedgwick, after visiting the locality, scouted the suggestion. Nevertheless they were undoubtedly worm burrows, and Macculloch's observations were confirmed some time after by Mr. R. J. Cunningham. Although the latter published his observations, the scientific mind was not prepared to change its opinion as to the azoic age of the Highland schists, and so these discoveries were allowed to drop out of sight. It was left to Mr. C. W. Peach, then

Comptroller of Customs at Wick, to convince the most sceptical that in the limestones that were seen to underlie the upper gneiss there occurred a considerable and diversified fauna. Examining, in 1854, the limestones at Durness, in north-west Sutherland, he found certain bodies which his keen and well-informed eye at once identified as shells. These were afterwards found to belong to seven cephalopods, seven gasteropods, one brachiopod, two annelids, two corals, and a supposed sponge, and to be of Lower Silurian age.

Mr. Peach, by this discovery, led the way to a complete revolution in Highland geology. Murchison again visited and made a rapid survey of the region, the result of his investigations being thus summarized by his biographer :—" Starting from the ancient platform of gneiss found on the western margin of Sutherland and Ross, he traced an ascending section through the undoubtedly Lower Silurian limestone and the vast overlying schists and gneiss up to the old red sandstone of the Highland border. He argued that as this overlying metamorphosed series had Lower Silurian fossils at its base, and was covered by old red sandstone at its top, it could not be anything but Silurian. And thus by one bold dash of the brush......he wiped out the old conventional mineralogical colouring which dated from the time when gneiss, mica-schist, and clay slate were supposed to be necessarily of higher

antiquity than any fossiliferous rocks, and substituted for it a mode of representation whereby the great mass of the Scottish Highlands was shown to consist of altered crystalline sandstones, shales, and other strata of Lower Silurian age. No such rapid change had ever before been made in the geological map of the British Isles."

This apparent demonstration of an ascending series of rocks, from the fundamental gneiss up through fossiliferous limestones to the gneiss and schists of the Central Highlands, was generally accepted as conclusive, and has since taken its place among the stock facts of geological manuals. Nevertheless, there have always been geologists who have stoutly opposed Murchison's reading of these Sutherland rock sections. His friend the late Professor Nicol maintained that the quartzites and limestones of Durness were younger than the crystalline schists overlying them. The latter, he held, were metamorphic rocks of pre-Cambrian age, that owed their present position above much later rocks to some gigantic overthrow fault that had turned the strata topsy-turvy. Professor Heddle, partly on chemical grounds, has advocated a somewhat similar view; so also has Dr. C. Callaway, who, after a careful study for some years of the region, lately published his conclusions in the *Geological Magazine*. One of these was to the effect that the Silurian schists of Murchison were

in reality of Archæan age, and that they have been brought over the quartzites and limestones by earth movements. Professor Lapworth, in a recent series of articles on "The Secret of the Highlands," has also taken exception to the Murchisonian view. The greatest credit, however, is due to the late Professor Nicol, who, a generation ago, had practically solved this question, but whose views were overborne at the time by the immense authority of Murchison. This great achievement—the result of many years of labour in the field—was to Nicol fruitful of little but estrangement. So much did he feel this, that when in later years he had worked out the subject in much greater detail, and could have given still better reasons for his geological belief, he declined, when pressed by friends to do so, to reopen a controversy associated with such bitter memories as the breach of the old friendly relations between himself and Murchison.

It was in the midst of these recent questionings of what had, by most people, come to be regarded as established fact, that the Geological Survey of Scotland, in pursuance of their work of mapping the Highlands, approached this bit of controversial ground. It was a special injunction from the Director-General to Messrs. Peach and Horne—the surveyors intrusted with the work—"to divest themselves of any prepossessions in favour of published views, and to map the actual facts in entire

disregard of theory." During two seasons the Durness and Eriboll areas were investigated by them, and their structure traced upon the six-inch maps. The results arrived at by Messrs. Peach and Horne were not in accordance with those of Murchison. Dr. A. Geikie, the Director-General of the Survey, then went north to inspect the work, and in *Nature* of November 13th 1884 he gives the results. "With every desire to follow the interpretation of my late chief," he says, "I criticised minutely each detail of the work upon the ground, but I found the evidence altogether overwhelming against the upward succession which Murchison believed to exist in Eriboll, from the base of the Silurian strata into an upper comformable series of schists and gneisses."

The evidence relied upon for this conclusion is detailed in the very able report by Messrs. Peach and Horne appended to Dr. Geikie's statement, but it is of too technical a character to be here entered upon. Suffice it to say, that owing to "prodigious terrestrial displacements to which there is certainly no parallel in Britain," to multitudinous foldings of the strata, reversed faults, and the most extraordinary dislocations, older rocks have been pushed over younger ones, with marked accompanying metamorphism, and thus sections have been produced which, had they "been planned for the purpose of deception, could not have been more

skilfully devised." The rocks thus turned topsy-turvy do not all belong to the same period, but include masses of Archæan, Cambrian, and Silurian age,—a circumstance which goes to show that those great movements took place subsequent to Lower Silurian times.

Important problems in Highland geology, it will thus be seen, have been opened afresh. They are, however, distinctly nearer solution by the removal, once for all, of Murchison's mistaken interpretation; and credit is due to the Director-General for the promptness with which he has made known the results of the recent survey of the Durness-Eriboll area.

XX.

THE DECAY OF BUILDING STONES.

If stones have never suggested sermons on decay, it is simply because the organic world supplies more appropriate texts. The grass is ever withering and the flower fading; but the living rock, like the everlasting hills, appears to short-lived man as if it would endure for ever. It is only necessary, however, to climb these hills in order to see how their constituent rocks are crumbling away under the influence of the various atmospheric agencies known to poets as "the gnawing tooth of time." There is no better proof, indeed, of the never-ending decay of rocks than the existence and formation of sandstones, these being simply the disintegrated materials of former rocks that have been consolidated by pressure and soldered together by the infiltration of lime or iron.

The rate at which decay in stone proceeds depends largely upon the climatic conditions to which it is exposed; thus, even mud as a building material

is fairly enduring in a rainless region. The "tooth of time," though gnawing for thousands of years at the pyramids of nearly rainless Egypt, has had little effect upon them; had they been raised, however, on the banks of the Thames or the Clyde, they could only have been continued to the present day by repeated restorations. Egypt is the paradise of outdoor monuments, and it seems a pity that any of those earliest signposts of the human race should be transferred to a country the climate of which is certain to shorten their existence. Pure air is as essential to the durability of certain building stones as it is to the health of living things; thus the carefully selected magnesian limestone of which the Houses of Parliament are built is, or at least was, fast falling a prey to the noxious ingredients of the London atmosphere; while there is hardly any building stone that does not last better in the country than in the town. Rain and frost are probably the main causes of decay in building stones; and when to these are added the sulphurous and other noxious vapours present in the atmosphere of large cities, it can be readily understood that in Britain, with its wet climate and great manufacturing centres, the conditions are peculiarly unfavourable to the durability of stone. Experience has shown, however, that certain of these building stones stand the British climate much better than others; it is for science, therefore, to discover what

in the composition or structure of these renders them more enduring than others. The latest of the very few scientific contributions to this subject is contained in a paper read recently before the Architectural Section of the Glasgow Philosophical Society, by Dr. William Wallace.

Sandstone is the chief building stone in use throughout Scotland, and it is with this stone alone that Dr. Wallace deals. He has analyzed samples of it taken from twelve well-known Scottish quarries, and these analyses show considerable differences in the composition of the various sandstones. Quartz or silica is, of course, the chief ingredient in all; but it varies in quantity from eighty-four per cent. in the white sandstone of Polmaise quarry to ninety-eight and one-fourth per cent. in that of Craigleith. The carbonates of lime and magnesia come next in importance, and these vary from twelve and a half per cent. in one sandstone to one-half per cent. in another. Those carbonates fill up the minute interstices between the grains of siliceous sand of which the stone is mainly composed, and thus make it more solid throughout. On this account Dr. Wallace puts great value upon their presence, considering "that the durability of a stone may, with tolerable accuracy, be deduced from the proportion of those compounds found in it." Authorities, if we mistake not, have generally regarded those sandstones as the best which consist almost

wholly of fine siliceous sand, with little or no lime; and it is an undoubted fact that the stone of Craigleith, which contains the largest proportion of siliceous matter and the smallest amount of carbonates, is at the same time the most durable of sandstones. Dr. Wallace is, however, inclined to regard Craigleith stone as altogether exceptional, the cementing material in this case being, as he thinks, probably silica itself, which, dissolved in water and percolating through the stone, has transformed it into what might be more appropriately termed quartz rock. Edinburgh is certainly fortunate in having such buildings as its University —the old part—and so many of the finest streets and squares in the New Town built of this well-nigh imperishable sandstone.

Oxide of iron is another ingredient found in all the sandstones examined, the quantity varying from two and a half per cent. to one-seventh per cent. in the different samples. The red colour of many sandstones is due to the presence in them of this substance; but it seems a somewhat anomalous circumstance that while the Wemyss Bay sandstone, which contains only one per cent. of iron oxide, is red, the Kenmure stone, with two and a half per cent. of it, is white. The colour of the stone would thus appear to afford no clew to the quantity of iron it contains. Dr. Wallace is inclined to regard the colouring effect of the iron in red sandstone as due

to its presence there in a free or uncombined state —that is, mechanically mixed; while in the white sandstone it is probably present in a state of chemical combination. Iron often occurs in sandstone in the form of pyritous nodules, which oxidize on exposure to air and moisture, and produce those dark stains by which so many otherwise fine buildings in Edinburgh and elsewhere are seriously disfigured. The pock-pitted aspect of many of our public buildings from this cause bears witness to the carelessness with which their stones must have been selected. Of some of the sandstones of this district, full of such impurities, Dr. Geikie lately stated that they ought never to be employed for architectural purposes. "Every block of stone in which they occur should," he adds, "be unhesitatingly condemned. Want of attention to this obvious rule has led to the unsightly disfigurement of public buildings."

Dr. Wallace also found that the various sandstones under examination differed considerably in weight and porosity, a cubic foot of the heaviest variety weighing 144½ lbs., while the same bulk of the lightest sort weighed 17 lbs. less. Porosity, as tested by the quantity of water the stones were able to absorb, was, as might be supposed, found to be greatest in the lightest varieties. Thus the least porous, that of Craigleith, was among the heaviest; while the least weighty, that of Bothwell

Park, was the most porous—the former absorbing 3.4 per cent. of water, and the latter 6.4 per cent., or nearly twice as much. The closest grained sandstone, it will thus be seen, is still considerably porous; and it is to the entrance and action of moisture through its pores that the decay of sandstone is mainly due. This moisture may act either chemically by the acids contained in rain-water, especially of towns, dissolving out the cementing material; or mechanically, by the freezing of the moisture in the pores producing expansion, and thus slowly disintegrating the stone. These causes act with exceeding slowness on vertical surfaces. The rain falling on flat surfaces, however, such as window sills and lintels, gathers there and gradually sinks through the porous material, too often making its presence visible in the disintegration of the stone at a slightly lower level. In passing along one of the Edinburgh streets lately, the houses in which are not more than twenty years old, the writer observed that over almost every doorway the vertical portion immediately beneath the projecting horizontal slab was thus fast wasting away, although the other portions of the polished sandstone fronts were for the most part intact.

To obviate as much as possible this fruitful source of disintegration, Dr. Wallace suggests to architects the avoidance, wherever they can, of perfectly flat surfaces, by giving to window sills

and all such projections as much slope as possible, so that water may run off. Such surfaces may also be protected by coating with silicate of soda—the so-called water glass—or with oil paint. A remedy of this kind applied to public buildings would, however, be considered by most people to be quite as hideous as the disease. The objection of disfiguring while protecting does not appear to apply to a new material called alexinoton, or damp repeller, manufactured by the Broxburn Oil Company, to which Dr. Wallace draws attention. He describes it as "the solution of a solid body in a highly volatile liquid," on applying which the volatile solvent evaporates, and the solid is deposited in, and thus closes up, the pores of the sandstone "without materially changing the colour or general appearance of the stone." The best qualities of sandstone stand, however, in little need of such artificial appliances, and Dr. Wallace's investigations go far to show that the heaviest and least porous sandstones are the best.

The best kinds of building stone for smoky and wet climates, according to Professor Hull, are siliceous sandstones; and it is a fortunate coincidence that the best of these are to found in greatest abundance in the mining and manufacturing districts of the north of England and the Lowlands of Scotland, where the atmosphere is most polluted. In the south and east of England, where the air is purer,

the limestones which form the chief British building material occur. The most important of these are the limestones of Bath and Portland. Bath stone has a fine grain and a yellowish-white colour, and is a favourite with builders on account of its softness when fresh from the quarry; it becomes harder, however, on exposure. Bath stone is not always to be relied on, for if built in before it is quite dry, it is apt to go to pieces should the following winter prove severe. "I have seen," says Sir Edmund Beckett, "a grand new hotel almost reduced to ruins in a single winter, all the *dressings*, or all except the rough walling, having been built of Bath stone." Most of the great ecclesiastical edifices of the west of England are built of this material; and although some of them date back to the twelfth century, they are still in good preservation. A somewhat similar although still finer limestone is that obtained at Caen in Normandy. It seems, however, to decay more readily in an atmosphere of coal smoke and sulphurous acid than Bath stone. It may be said to have come over from Normandy with the Conqueror, and was a favourite building material for churches—for example, Canterbury Cathedral and Westminster Abbey—until Normandy was lost to the English Crown.

It is a common error to suppose that sandstone will stand fire better than limestone. After the burning down of the old church at Doncaster, this

question was raised with the view of obtaining the most fire-proof stone with which to rebuild the pillars. The experiment, according to Beckett, was tried of keeping two large blocks in a fire until something decisive should happen. The sandstone, it was found, very soon flew to pieces, while the limestone, even after twenty-four hours' exposure to the heat, was only burned a little on the surface.

The evidence afforded by tombstones of the rate at which various building stones decay was brought under the notice of the Royal Society of Edinburgh a year or two ago by Dr. A. Geikie. He there showed how exceedingly durable properly selected sandstone was by a reference to the tomb of Alexander Henderson, in Old Greyfriars' Churchyard, which has changed so little during two centuries that the chisel marks and the lettering on the surface are still distinct and sharp. As an instance, on the other hand, of a badly selected sandstone, the case is given of a monument in the same churchyard, erected to an officer in 1863, on which the sharply-cut date is no longer legible, about one-eighth of an inch of surface having been removed from the stone in the course of sixteen years. Of other monumental stones marble is one of the commonest; yet Dr. Geikie found that this favourite material lost its polished surface, through superficial solution, after exposure for a year or two to our prevalent westerly rains, and that inscriptions

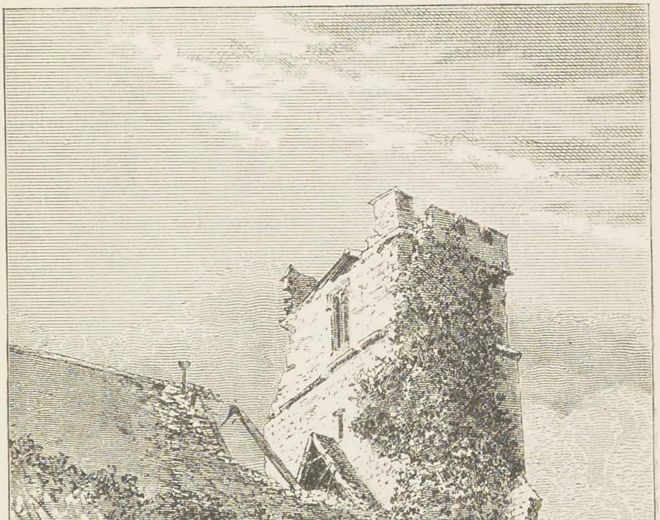
on it usually become illegible in about twenty years. He found, however, that when protected from prevalent winds and rain the inscriptions on marble might remain legible for a century at least. In some cases a crust of town dust is formed on the surface of the marble, which has the effect, so long as it remains unbroken, of preserving the smooth surface of the slab, although all the while the stone is fast decaying beneath. In other cases, where the marble slab is fixed, as it usually is, in a setting of sandstone, it by-and-by expands—probably through the action of frost on its contained moisture—and is thus made to swell up in the centre, and eventually to get fractured. White marble, he accordingly concludes, is utterly unsuited for out-of-door use in our climate, and its employment for works of art which are meant to stand in the open air should, he considers, be strenuously resisted. Granite has not yet been long enough in use as a monumental stone to afford satisfactory data as to its durability in the atmosphere of towns; a polished granite surface, however, shows no apparent signs of decay after an exposure of from fifteen to twenty years.

XXI.

BRITISH EARTHQUAKES.

THE record of British earthquakes extends back for nearly a thousand years, and contains the chronicle of more than three hundred of those "shocking" occurrences. That the number would have been much larger had the record been more accurately kept is tolerably certain, seeing that the present century is already credited with more than half of the entire number. Better chronicling can hardly, however, account for the whole of this enormous increase; some of it must, no doubt, be held as marking an actual increase in the frequency of those occurrences during the present century.

Most of these latter-day earthquakes have been of a comparatively trifling character; but that the seismic energy beneath our feet is still capable of manifesting itself with all the energy of former centuries was seen in the severe earthquake shock felt on the morning of Tuesday, April 22, 1884, over the south-eastern counties of England. Almost



LANGENHOE CHURCH.

Showing effect of earthquake shock of April 22, 1884.

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exactly five centuries ago (1382) the south-east of England was visited by a similar earthquake, which threw down several churches, and otherwise did much damage; but neither it nor any British earthquake since would seem to have done so much injury to property as the one which lately had its centre at Colchester. The undulation of the ground, as the earth-wave passed from south-east to north-west, was so marked that people in Colchester experienced "a sensation approaching that of nausea." There, also, it was accompanied by loud subterranean rumblings, while over a wide area its effects were painfully visible in the fall of chimney-stacks and church spires, and the complete or partial wreck of a large amount of valuable property.

If chroniclers are to be trusted, some of the early British earthquakes would appear to have been of a more serious character than any of later date. Thus the whole of England was said to have been shaken by an earthquake near the close of the tenth century. A hundred years later another occurred, the "heavy bellowing" of which was heard throughout the land. The twelfth century appears to have been one of exceptional seismic energy. In 1110, for example, an earthquake shook the centre of England, and laid bare for some hours the bed of the river Trent at Nottingham. Fifty years later, London was similarly visited, and the Thames dried up, so that it could be crossed on foot. During another severe

earthquake in 1134, "flames of fire burst forth with great violence out of certain rifts of the earth;" and in 1185 a similar visitation destroyed Lincoln Cathedral. This period of subterranean disturbance continued till near the end of the thirteenth century, Wells Cathedral having been overthrown, and that of St. David's seriously injured, by an earthquake in 1248; while the last of the series—that of 1275—is said to have damaged or destroyed many of the largest churches in England.

After the earthquake of 1382, already referred to, there appears to have been no shock of any importance in Britain until the middle of the eighteenth century, with the exception probably of that of 1608. The latter was felt all over Scotland; and, as was usual in those days, it was generally regarded as a token of Divine wrath. The kirk-session of Aberdeen, indeed, believed it to be largely due to the particular sins of that city, and appointed a solemn fast for the following day. The minister of Dunfermline would seem, however, to have regarded seismic energy at that time as largely Satanic; for on being asked by King James VI., then a boy, why, during a previous earthquake, the house of the Master of Gray should alone have been shaken, he is said to have replied, "Sir, why should not the devil rock his ain bairns?"

With the middle of the eighteenth century there began a period of subterranean disturbance which,

with short intervals, has continued ever since. In 1749 a shock occurred at Leadhills which caused the people to run out of their houses. In the following year London was twice visited within a month by earthquakes. These brought down some chimneys, broke chinaware in shops, and damaged the towers —then nearly erected—of Westminster Abbey. The belief got abroad that at the end of another month there would be a third and severer shock, and London for the time became panic-stricken. Great numbers left the city, and on the evening preceding the day of the expected earthquake the roads out of London were crowded with vehicles. "Earthquake gowns"—warm garments to wear while sitting out of doors all night—were in great demand. Many people, says Walpole, "sat in coaches all night in Hyde Park, passing away the time with the aid of cards and candles." No earthquake came, but during that year scarcely a month passed without a shock being experienced in some quarter or other of England. Five years later came the great earthquake which in five minutes destroyed great part of Lisbon, with sixty thousand of its inhabitants. This mighty shock made itself felt over the whole of Britain, its influence being chiefly seen in the agitation of inland lakes and streams. The waters of Loch Lomond thus rose suddenly on its banks, so that a boat was carried forty yards inland. They then receded, but rose again soon after; and this

peculiar agitation lasted for an hour. Women washing clothes on the banks of the Tay were swept off their feet by a wave; while a great sea-wave entered the harbour of Kinsale, damaging the shipping and deluging the market-place. Five distinct shocks were felt at the same time in one of the lead mines of Derbyshire, the second being, as it was also at Lisbon, the most violent. 1784 was the year of great volcanic outburst in Iceland, when the ashes from its burning mountains fell in showers of fine dust over the north of Scotland. This may probably explain the disturbance observed at the time in the waters of Loch Tay. These were seen to recede from the two ends and to rise in a great wave in the centre, then to flow shorewards, where they rose far above the usual level. A destructive earthquake occurred in Italy in 1789; and on the same day, according to a notice in *The Scots Magazine*, "three distinct shocks of earthquake were felt at the house of Parson's Green, on the north side of the hill of Arthur Seat, near Edinburgh." Shortly after, that most mobile of British localities, Comrie, had the ice on a lake in its vicinity suddenly shattered into atoms.

The recorded British earthquakes of the present century are for the most part Scottish. In 1801 the New Town of Edinburgh was thus visited, while, strange to say, the Old Town escaped. The sensation experienced was "as though the houses had

been lifted bodily upwards, and then violently shaken from north to south." Some damage was done to property, and two lives were lost, through this earthquake. One of the most notable of Scottish earthquakes was that of 1816, which made itself distinctly felt all over the northern countries. In Aberdeen, house bells were set a-ringing, and a rumbling noise was heard; in Montrose, people leaped from their beds, imagining their houses were falling; and three arches over an arm of the sea at Dornoch were thrown down. The shock, however, appears to have been most severely felt at Inverness, where people were said to have been actually thrown from their beds. Houses were rent from top to bottom; a coping-stone, weighing fifty to sixty pounds, was thrown a distance of about twenty yards; the steeple of the county jail got a twist a few feet from the top, and the town bell was heard to toll. The year 1839 witnessed a remarkable exhibition of seismic energy in Scotland, no fewer than one hundred and forty earthquake shocks having been felt at Comrie, during a period of about five months. That of October 23rd was the most severe, the shock being felt over nearly the whole of Great Britain. The terror in Comrie was so great that the people left their houses, and spent most of the night in prayer at the Secession Meeting-house. The great dam for supplying the Carron manufactories with water was burst by the shock, and much damage was done by the

flood that followed. Wells in some parts of the country ran temporarily dry, and bogs were drained. The west of England was visited by a severe earthquake in 1863, which in Hereford was accompanied by a noise compared to that of "a very heavy and long train rushing furiously through a station;" while another occurred over the same region in 1868. November 1880 is memorable for the series of disastrous earthquakes which laid the greater part of Agram in ruins. About two weeks later an earthquake passed over the northern parts of the British Isles. It was chiefly felt along the central valley of Scotland and in the north-east of Ireland, and had sufficient force to ring house bells in Bute, and to bring down portions of plaster from roofs in Inveraray.

A study of British earthquakes shows that, in many instances, they were contemporaneous with similar events or with volcanic phenomena in other parts of the world; and many geologists have adopted the theory that our earthquakes belong to one and the same system with those which vex the south of Europe and North-western Africa—a system which is supposed to have its seat and centre in the region of the Azores and Cape Verd Islands. Whether connected with Continental seismic disturbances or not, it is evident that there are certain districts of Britain more liable to those visitations than others. This is notably the case with the neighbourhood of Comrie, in Perthshire, where no

fewer than two hundred shocks were experienced during the four years subsequent to September 1839. Three hundred years ago the kirk-session might have attributed those too frequent visitations to the many faults of the parishioners; it is the best geological opinion of the present day that they are due to a huge fault in the rocks of that region. There the old red sandstone rocks have been thrown on end against the crystalline schists of the Scottish Highlands, and the dislocation thus produced has been traced by Dr. A. Geikie right across Scotland, from Stonehaven in the east to Arran in the west. "So far as geological structure can be supposed to govern the origin and effects of earthquakes"—to quote from a recent paper on the subject—"there does not appear to be within these islands any line or district where terrestrial disturbances should be so readily felt as along the flanks of the Scottish Highlands."

Although earthquake phenomena have been under man's observation in all ages—the record of over seven thousand of these, in which thirteen million of the human race are estimated to have perished, being preserved—it is only of late years that they have received exact scientific investigation. Nor can it be said that as yet much is really known regarding their origin. The theory that the Earth has a liquid interior, surrounded by a thin crust of solid material, and that movements in the former propagate earthquakes in the latter, is not so widely

accepted now as formerly. That earthquakes are vibratory concussions propagated through the solid crust of the Earth like waves of sound in the atmosphere, is generally conceded; the initial shock, however, may be, and probably is, produced in a variety of ways. A great landslip, such as that of the Rossberg, has been known to produce a slight tremor in the surrounding country, and the sudden collapse of great subterranean caverns may be held sufficient to produce a similar result.

If the interior of the Earth be not a liquid mass, there are at least reservoirs of molten matter beneath its surface, as is shown from the outflow of lava from the craters of active volcanoes; and that water from the surface may reach those lakes of fire, and be there converted into steam, is exceedingly probable. The effect of the sudden generation of steam in the bowels of the Earth would naturally be disruptive, and it is a favourite theory of seismologists at the present day that steam under those conditions plays an important part in the genesis of earthquakes. There are other reasons, however, for believing that the phenomena of earthquakes and volcanoes are intimately connected with each other.

Whatever mystery still surrounds the origin of those vibratory shocks, the effects of which are at times made so painfully visible on the Earth's surface, much has been learned of late years regarding their outward manifestation—their rate and modes of

progression, etc.,—and it is possible that our knowledge on these matters may yet ripen into the ability to foretell the coming of an earthquake, just as the meteorologist is beginning to turn his knowledge to account in forecasting the weather. Professor Palmieri, the greatest living authority on the subject, in a recent lecture stated his belief that earthquakes have longer or shorter periods of preparation; that for some time before as well as for some time after a great shock the Earth is in a state of physical perturbation, and that this disturbance dies away or increases according as the earthquake is past or only approaching. Palmieri believes that, by registering those slight premonitory tremblings, and observing their increase or decrease, it would be possible to foretell an earthquake by at least three days. To obtain the necessary data, however, a network of seismographic stations would have to be established, and these put in telegraphic communication with each other. In this way he considers it would be possible in most cases to issue earthquake warnings to threatened districts. A system of stations for making such observations is, we understand, at present being organized in Switzerland—probably the most physically disturbed country in Europe; and Professor Milne of Yokohama has been lately endeavouring to obtain the co-operation of Japanese officials in securing similar observations in Japan—a country probably the most earthquake-vexed in Asia.

XXII.

MICROSCOPIC EARTHQUAKES.

THE recent calamities at Ischia and in Java show how far removed our world is from the category of things that cannot be shaken. Although, fortunately, the area of the globe vexed by those sudden and violent movements known as earthquakes is comparatively limited, it is to be feared that perfect stability characterizes no part of the terrestrial surface. Bertelli demonstrated some years ago that the soil of Italy was in a state of constant vibration, and Professor Milne has shown that the same is true of Japan. This is, however, the less remarkable, as those countries are centres of volcanic and seismic energy. It is not surprising that the incessant throbbings of Etna and Vesuvius and the convulsions of Calabria should make themselves felt in earth-tremors all over the peninsula. The brothers Darwin, however, have lately shown that the soil of Britain, in which volcanic energy has ceased for ages, is similarly moved.

Although the globe, as physicists now tell us, is solid, it possesses an elasticity which makes its surface exceedingly sensitive to comparatively slight pressure. The Astronomer-Royal informed Mr. G. Darwin that about twenty years ago, when vast crowds used to visit Greenwich Hill during the Fair, and to amuse themselves by running down hill, the ground shook so that certain astronomical observations could not be made for some hours after the crowds had dispersed. Any one standing at a railway station as an express train rushes past is distinctly conscious of earth-tremors beneath his feet, and with fairly delicate apparatus such tremors have been readily detected at the distance of a mile.

Professor Milne determined the presence of earth-tremors in Japan by means of microphones fixed on stakes driven into the ground. A person running or walking in the neighbourhood of those delicate instruments had, he says, "his steps so definitely recorded, that a Japanese gentleman who assisted me in the experiments caused the swinging needle of his galvanometer to close an electric circuit and ring a bell"—a contrivance by which he suggests earth-tremors might be utilized as thief-detectors.

The vibrations produced by such artificial causes as railway trains are sufficiently serious to impair the efficiency of astronomical instruments set up in their neighbourhood. A deep cutting, however, generally suffices to interrupt, for the most part,

such local disturbances. Thus, Major Palmer, when seeking a station from which to take observations of the transit of Venus, found escape from the tremors caused by a railway four hundred yards off by digging a trench large enough to hold himself and his instruments. No known precautions, however, are sufficient to get rid altogether of the microscopic movements due to local disturbances; at least such was the experience of the Darwins in the experiments lately carried out by them at Cambridge. The object of their investigation was to discover how far the moon's attraction of the Earth disturbs gravity. This they sought to find by means of a pendulum so constructed that its slighest movement, by being magnified fifty thousand times, could be readily seen. The most elaborate precautions were taken to cut off all merely local perturbations, such as fixing the apparatus in a stone block weighing three-quarters of a ton and bedded in a pit, the immersion of the pendulum in a tank of water, and the further enclosure of the whole apparatus by a trench, also filled with water. All, however, was in vain, for so sensitive was the apparatus that the least movement of the observer even sixteen feet away produced motion in the pendulum. The latter, indeed, was found to be rarely if ever steady, and the brothers despair of being able to work out the problem of the lunar disturbance of gravity by this method until they can find a more stable foundation

for their apparatus. This they think might possibly be found at the bottom of a mine.

While the tremors which agitated the delicate apparatus at Cambridge were to a considerable extent due to artificial local disturbances, it was also noted that there were periods, lasting for several days, when unusual agitation prevailed, which could not be thus accounted for. M. D'Abbadie, investigating earth-tremors in the south of France by means of reflections from a pool of mercury, also found that there were periods of agitation and quiescence in the mercury without perceptible external cause. Other observers have obtained similar results in different quarters of the globe, thus rendering it highly probable that those minute earth movements are a universal phenomenon. Little has yet been learned of their true nature, but, judging from what is known, Professor Milne considers it not unlikely that they may be to our continents what tides are to our oceans—phenomena which are regular and law-abiding, and not like earthquakes, which may be compared to the storms of the ocean.

The same seismologist has recently drawn attention to what he believes to be a third class of earth movements — namely, earth - pulsations. Unlike earth-tremors, these movements are of great amplitude, but have hitherto been overlooked, owing to the slowness of their period. He believes in their existence partly on theoretical grounds and partly

from direct evidence. Mr. G. Darwin has shown that the result of the variations of barometric pressure on an elastic, yielding body like the Earth, must be to produce corresponding variations in the level of the ground. A rise of the barometer over a given area means an increased weight of atmosphere upon it; and it has been calculated that a rise of an inch in the barometer over Australia—assuming the Earth to be extremely rigid—is enough to sink that continent two or three inches. On the other hand, a fall of an inch means the removal of this extra load and the consequent rise of the crust, by virtue of its elasticity, to its old level. A similar result would seem necessarily to follow from the rise and fall of the tides. Twice a day these are piling up an immense weight of water on our shores, and as often removing it again, and Mr. G. Darwin calculates that a rise and fall of five inches in the land is being thus constantly effected on the shores of the Atlantic. If variations of the barometer and the rise and fall of the tides are thus effective in raising and depressing the ground, evidence of it should be found in the behaviour of the stile of a delicate pendulum. It ought to show a certain displacement in the vertical; and although, as has been already pointed out, it is impossible altogether to eliminate the effects of purely local disturbances on the movement of an extremely delicate instrument, yet fairly satisfactory evidence has been afforded that such

displacement of the vertical actually occurs, those "tips of the soil" appearing to be connected with barometrical variations.

Direct evidence of the occurrence of earth-pulsations too slow in period to be felt, Professor Milne finds in certain phenomena that have been noticed in connection with great earthquakes. The earthquake, for example, which laid Lisbon in ruins produced no perceptible motion in the soil of Northern Europe; that there was movement, however, is proved by the fact that throughout the northern hemisphere slow oscillations of the water in lakes, ponds, and canals were observed. Thus the waters of Loch Lomond rose and fell through about two and a half feet every five minutes, and other British, Scandinavian, and North American lakes were similarly agitated. The short, quick vibrations which proved so destructive in Portugal would thus seem, according to Professor Milne, to have gradually changed as they radiated outwards into long flat waves, which, by the time they reached Britain, had become "too gentle to be perceived, excepting in the effects produced by tipping up the beds of lakes and ponds."

That such earth-pulsations accompany all great earthquakes seems more than probable from such cases as the following, adduced by Mr. G. Darwin in a recent report to the British Association:—Oscillations in the bulb of a level were observed at Pul-

kova Observatory, in Russia, an hour and fourteen minutes after a severe earthquake at Iquique, seven thousand miles away. Similar phenomena were observed twice previously, and on each occasion it was learned afterwards that earthquakes had taken place some minutes before at places more or less remote. Similarly, also, an earthquake at Santiago, a few years ago, made itself felt on the clocks in the watchmakers' shops of Buenos Ayres, those oscillating north and south increasing twofold the amplitude of their oscillations, yet no motion of the ground was perceptible. Although seismologists have devoted their attention almost exclusively to the study of earthquake phenomena, they have not yet succeeded in throwing much light on the origin of these subterranean convulsions. It is possible that the careful study of these microscopic movements of the Earth's crust—its tremors and pulsations—may afford a clew to the laws which govern the greater earthquake movements.

XXIII.

RECENT METEORITES.

EXCEPTING light, meteorites are our only source of information regarding the universe outside of us, and hence the interest with which those celestial visitants are everywhere regarded. In pre-scientific days they were considered as the thunderbolts of angry gods, and temples were built over them, in which the worshippers sought to appease the divine wrath; now-a-days they are weighed, measured, and analyzed, preparatory to taking their place beside similar objects in museum collections. The British Museum, according to a lately-issued catalogue, possesses no fewer than three hundred and fifty-one of those meteorites, and the Vienna National Collection is even more celebrated, while there are few museums in either hemisphere that do not possess one or more of those unearthly specimens.

Considerable diversity exists in their composition, some being formed chiefly of native iron, alloyed with more or less nickel, others partly of iron and

partly of stone, while the largest number consist almost wholly of stone. Twenty-four out of the sixty-four recognized elements which go to form the Earth's crust have been met with in meteorites; but no new element has been discovered, although they have yielded seven new minerals.

They vary in weight from grains to tons. That found at Cranbourne, near Melbourne, in 1861, weighed nearly four tons; while another found in Brazil was estimated to weigh fourteen tons. The latter, however, was altogether eclipsed by the largest of three masses of iron found by Nordenskiöld in 1870 at Ovifak, in Western Greenland, which weighed twenty-two and a half tons, the other masses weighing fourteen and four tons respectively. The investigations of Professor Steenstrup and others into the character of the surrounding rock—a basalt with nickeliferous iron disseminated through it—render it highly probable, however, that those apparently meteoric masses have had a terrestrial origin. Stone meteorites are small in comparison with those meteoric iron specimens, the largest of the former, now in the Vienna collection, weighing only six hundred and forty-seven pounds. It is a curious fact, also, that while nearly all the recorded meteoric stones have been seen to fall, only a comparatively few of the meteoric iron specimens have been so observed. Thus, of the hundred and eighteen iron meteorites in the British Museum col-

lection, only seven were seen to fall. This is probably due to the fact that a meteoric stone is much more difficult to recognize than meteoric iron, so that only those stones which are seen to fall would be likely to be picked up; while of the many meteorites which come to earth, without being found at the time, those of iron will have much more chance of being afterwards recognized.

The number of those bodies which reach the Earth's surface would appear to be comparatively few, judging by the number of recorded instances. Dr. Flight of the British Museum has lately published, in the *Geological Magazine*, a list of all the meteorites recorded since 1870, and these do not exceed on an average two for each year. During that period two have fallen in Britain—one at Rowton in Shropshire, in 1876, and another near Middlesborough in Yorkshire, in 1881. The former specimen is an iron meteorite, weighing seven and a half pounds, and is the second of the kind ever found in Britain. Its passage through the air was accompanied by a rumbling noise, followed by a startling explosion resembling a discharge of heavy artillery. On striking the earth it buried itself to a depth of eighteen inches in clay. It contained ninety-one per cent. of iron, eight and a half per cent. of nickel, and minute quantities of cobalt and copper. The stone meteorite which fell at Middlesborough in 1881 weighed three and a half pounds. It came

down with a whizzing noise, and buried itself eleven inches in the ground within forty-eight yards of the two men who observed it.

During the year 1882 three meteors have been recorded. In two of these cases, however, the meteorites do not appear to have been found. One of these occurred in Indiana, United States, and seems to have been of a more than usually alarming nature. A party of men riding home during a snowstorm at eleven in the evening suddenly became aware of a large meteor moving near them with enormous velocity. It had the colour of melted iron, the light being so brilliant as to blind them, while lighting up the entire neighbourhood as clearly as the brightest day at noon. When nearly overhead it exploded with a tremendous report, the force of the explosion breaking the glass in the windows of the surrounding houses. "The entire party," it is said, "were prostrated, horses and men, and some of them did not recover their sight until some twenty-four hours later." The third meteor, unlike the other two, yielded an almost unprecedentedly rich crop of meteorites. At Klausenburg, in Transylvania, an intensely brilliant meteor was observed in broad daylight, and in a cloudless sky. After loudly detonating, the meteor appears to have broken up, as quite a shower of stones fell at Mocs, about five miles from Klausenburg. About two thousand meteorites, it is calculated, fell on this

occasion. With the exception of the Pultusk fall in 1868, when several thousands of stones, varying from the size of an orange to that of a nut, were picked up, there has probably been no such shower since that of 1803 at L'Aigle, when about three thousand stones fell—a shower which, investigated by Biot, finally set at rest the question of the cosmical origin of meteoric stones.

The only recorded meteorite of 1880 fell in La Plata, and belonged to that rare group of stones containing carbonaceous matter. Such an ingredient permeating a rock on our globe would, as Dr. Maskelyne remarks in one of his papers, assuredly be accepted as a product resulting indirectly from animal or vegetable existence. He, however, favours the view that this unusual ingredient has been taken up by meteoric stones after their formation, probably in passing through a hydro-carbonous atmosphere. Others, however, may regard the presence of carbonaceous matter as lending countenance to Sir William Thomson's hypothesis of seed-bearing meteors.

The theory that meteorites are bits of other worlds which have animals and plants comparable to our own was lately reinforced by the publication of a veritable curiosity in scientific literature—Dr. Hahn's "Meteorites and their Organisms." In this he claims to have shown the presence in certain meteorites of sponges, corals, and crinoids; ocular demonstration of which he seeks to give in photographic reproduc-

tions of over one hundred thin sections of meteorites. Dr. Carl Vogt has gone carefully into this matter, and he finds that all the pretended organic structures are purely inorganic, and that in no single case do they present the microscopic structure of the organisms for which they have been mistaken. The forms are well known to students of this branch of mineralogy, and are due to the presence of certain radiating varieties of minerals fractured in a peculiar manner. Dr. Hahn's laborious work must therefore be placed alongside that of the German professor who found in his microscopic examination of basalt a whole flora and fauna, the members of which he proceeded to dub with double Latin names. The specimens on which Dr. Hahn worked were stone meteorites belonging to the group known as chondrites; but meteoric iron when cut and polished, and exposed to the action of acids, also develops peculiar markings, known in their case as Widmanstätten figures. These result from the unequal action of the acid on the various constituents of the meteorite, and thus prove its want of homogeneity. These figures do not invariably appear on meteoric iron, being seldom found in specimens containing more than nine per cent. of nickel. So much nickel is, however, exceptional, although the British Museum possesses one meteorite with thirty-four per cent., and another with sixty per cent., of the metal.

Meteorites are invariably covered with a crust or varnish, the result of the intense heat generated on their exterior during their fall through the Earth's atmosphere. They enter our air cool with the intense "cold of space," but the resistance they meet with during the few seconds occupied in their descent to the ground raises their surface to the point of fusion, the molten matter being wiped off by the resisting air and going to form the meteor train. Intense as is the heat at the surface, the descent of the meteor is too rapid to allow that heat to get far below the surface. The interior of a large meteorite, therefore, probably retains in its descent the low temperature with which it entered the Earth's atmosphere. This may explain the circumstance that although most of those stones which have been handled soon after their fall have been found to be warm, others have been spoken of as cold. Some meteorites which fell in the Banat, Hungary, in 1875, and which were picked up immediately, were quite cold; while the stones which fell at Dhurmsala, in India, in 1860, are said to have been so cold that they could not be held in the hand. It is this sudden generation of heat on the outside of the meteorite, and the consequent expansion of the heated part, which causes the breaking up of the mass into fragments, and the accompanying thunder-like noise—often loud enough to be heard forty miles off.

The indestructible part of what is burned off the meteorite in its descent falls to the Earth in the form of meteoric dust as certainly although more leisurely than the meteorite itself. This cosmic material has been found in the snows of mountain tops, and in the mud of the deepest sea bottom. It is indeed everywhere, and in the long ages must have contributed materially to the building up of the Earth's crust. Little of this meteoric dust, however, has been given off by the meteorites which reach the Earth's surface. Four hundred million meteors, it is computed, enter our atmosphere annually, and possibly not more than half-a-dozen of these are big enough to reach the ground. The others, as shooting stars, burn themselves out in a momentary streak of light, and only reach the Earth in the form of the finest dust. No meteor of the prolific November showers has ever been recorded as having reached the ground, and the researches of Professor Herschel have led him to conclude that the November meteors weigh on an average but a few grains each.

Whatever the origin of those meteors, whether original members of our solar system or incomers from interstellar space, they are now believed to form systems, each of which moves round the sun in a definite orbit, and it is only when the Earth crosses those orbits that meteoric showers occur. It is highly probable that those "pocket planets"—

as meteorites have been called—which reach the Earth's surface, do so through being intercepted by the Earth crossing the orbit of the meteoric system to which they belong. Not only is there evidence to show that meteors move round the sun in definite orbits, but it is now well ascertained that in at least four of those meteor systems their orbits are identical with those of well-known comets. The connection between meteors and comets can only as yet be surmised, although some astronomers have adopted the view that the former are merely cometary fragments which the latter have from time to time thrown off.

XXIV.

METEOR SHOWERS.

In the days when men worshipped stocks and stones, it is not surprising that meteorites, as having come down from above, should have received the homage due to their supposed celestial origin. Since they became objects of scientific investigation they have formed a sort of astronomical puzzle, the attempt to solve which has given rise to much ingenious speculation: at one time being regarded as purely meteorological phenomena, taking their rise and running their course under strictly terrestrial conditions; at another as having had their origin in the moon or some other member of the solar system. The favourite theory for long was that of Laplace, which accounted for them on the supposition that they were hurled at us from lunar volcanoes. Recent researches have, however, supplied us for the first time with a theory claiming to be based on well-ascertained facts, and which at the same time invests those mysterious visitants with an interest greatly

exceeding that aroused by previous speculations on the subject.

Meteorites are now regarded by most astronomers as intimately connected with, if not actually forming fragments of, comets. In reaching this conclusion it has been necessary to show that the comparatively rare meteorite is, astronomically considered, identical with celestial phenomena of a much more familiar description—namely, with fire-balls and shooting-stars, the latter of which may be seen, in greater or less abundance, during any clear night. These have been proved to the satisfaction of astronomers generally to be all alike solid on their entrance into our atmosphere, any after difference in their behaviour being simply due to difference in their initial bulk. They all rush, as solid bodies, into our atmosphere at enormous speed—probably about forty miles per second; with the result that both air and meteorite get intensely heated, owing to the friction of the one upon the other. The outside of the stone gets melted off as a piece of tallow would if drawn over an iron surface at a white heat, the molten matter being wiped off by the resisting air, and going to form the meteor train. In the vast majority of cases the aërial friction is sufficient to dissipate the whole of the meteoric stone into vapour or the finest dust, and then it appears to beholders as a shooting-star.

It is a fortunate circumstance for man that so

many meteors thus merely play the part of celestial fire-works; for, according to Professor Newton of Yale College, United States, no fewer than four hundred millions of meteors enter the Earth's atmosphere every year, and were any considerable proportion of these to reach the ground in the solid state, life of all kinds would become sufficiently precarious, as the minutest of these, owing to their extreme velocity, would undoubtedly strike with fatal effect. The force with which such as reach the Earth strike it, and the heat which they acquire in their rapid progress downwards, were well illustrated in a meteorite weighing twelve pounds, which fell some time ago in California, it having buried itself eight feet in the ground, and being, when dug out, so hot that it could not be handled. It is only the largest, however, of the meteoric stones, and these are exceedingly rare, which do not become wholly dissipated before reaching the ground; from all others the air is, as Professor Newton expresses it, "a shield to protect us from an otherwise intolerable bombarding."

That the countless hosts of shooting-stars which thus burn themselves away in our atmosphere were originally solid bodies, like true meteorites, might be inferred from the results of recent investigations on the subject of meteoric dust. Recent researches have proved that meteoric dust exists in much greater quantity than has hitherto been suspected. Meteoric stones abound in iron, and black angular

particles of this metal have been found by Nordenskiöld on the snow near Stockholm and in ice-holes in Greenland, while it was detected during the late Arctic Expedition in regions of palæocrystic ice. It has likewise been found high up among Alpine snows, and analysis of the mud of sea bottoms collected during the *Challenger* expedition has shown it to abound on the floor of the ocean. So universal and so considerable is this fall of cosmic dust, that it must in the lapse of ages contribute materially to the matter of the Earth's crust. Whence came the bulk of this material, if not from the condensed metallic vapours of countless shooting-stars?

Meteorites being thus held as astronomically identical with shooting-stars, whatever is proved regarding the origin of the one may be taken as equally applicable to the other; and there is now sufficient evidence to show that meteors or shooting-stars are grouped together in systems or families, each of which moves round the sun in a definite track or orbit, their existence becoming known to us when the Earth in her journey round the sun crosses the meteor path. Our knowledge on this subject has been chiefly gained from a study of the Leonides group, better known as the November meteors. These course round the sun in an elliptical ring, the furthest point of which is nearly twenty times further removed from the central luminary than is our Earth; that is, twenty times more than ninety-

two million miles. The mighty orbit thus formed measures seventeen hundred million miles in length, and along this the November meteors move, not in a single compact mass, but extended out so that they take several years to pass a given point, the path, however, being more thickly strewn with meteors in some places than in others.

It is not to be supposed, however, that even in the "gem" of this spacious ring meteors are in reality densely packed; for, as Mr. Proctor has shown, the appearance of ten or twelve meteors in a second, which would constitute an exceedingly rich star-shower, would, were they even all to show themselves in exactly the same part of the sky, only indicate the presence of that number of minute bodies spread over a space forty miles in length, which is the distance travelled by the Earth in a single second over the meteor path. That the meteors belonging to the family Leonides are individually small may be inferred from the fact that there is no recorded instance of any one of them ever reaching the surface of the Earth, unless indeed in the form of meteoric dust—the indestructible residue of that streak of light which marks the aërial path of the shooting-star; and the researches of Professor Herschel have led him to conclude that the November meteors weigh on an average but a few grains each.

Our knowledge of the existence of this system arises solely from the fact that the Earth annually,

about the middle of November, crosses the meteoric path, intercepting such meteors as happen to be in the way, and bringing them into our atmosphere, where, before disappearing for ever, they disport themselves as shooting-stars. If the part of the track crossed by the Earth should chance to be thickly strewn with meteors, those brilliant showers which occasionally light up our dull November sky ensue. The chief displays of this kind have been observed to occur at intervals of about thirty-three years, the last having occurred in 1866 and the year following, while another of equal brilliancy need not be expected till the closing year of the present century. The fact that those reach us at such intervals indicates that a period of about thirty-three years is occupied by the meteor stream in making a single journey round its enormous and eccentric orbit.

Other well-known meteor-showers occur in the middle of August, the end of November, and during April, each of which forms a system through which the Earth plunges at those times, and there is already evidence to show that no fewer than two hundred such systems are thus annually crossed. The number of similar systems existing throughout interplanetary space, but which, as the Earth does not cross their paths, can never become known to us, must be enormous, and probably justifies the assertion of a recent writer on this subject, that the whole of the solar domain is alive with meteors.

It has been further observed that certain families of meteors follow in the track of particular comets. This has been proved in the case of the August meteor-showers, the Perseids, whose orbit is similar to that of a bright comet which appeared in 1862; also with the early November meteors, which travel along the same road as Tempel's comet. Such appears also to be the case with the later November showers, which are specially interesting from the fact that they are the attendants of a missing comet, Biela's, which was first fully discovered in 1826, although twice seen before, and regarding which nothing remarkable was at that time observed, save the fact that its path was such as nearly to cross that of our Earth. Revolving round the sun in a period of nearly six and three-quarter years, its predicted appearance in 1832 was the cause of very general alarm, owing to the fear entertained of a collision between the comet's head and our planet. As astronomers had foretold, however, the comet crossed the Earth's orbit fully a month before the latter reached the same place, and the collision was thus avoided, and the question of the behaviour of our Earth under such peculiar circumstances was left unsolved. Once in every three revolutions Biela's comet is, or rather was, so placed as to be lost to view in the sun's rays; in 1839, therefore, it was hopeless to look for it, but in 1846 it re-appeared in its usual form. Not many days after,

however, while its behaviour was being closely watched by astronomers, to their astonishment it was observed to divide into two, each with its own head, coma, and tail, while before vanishing the severed halves had got one hundred and sixty thousand miles asunder. Their return after another revolution period was eagerly awaited, and in 1852 astronomers had the satisfaction of noting the reappearance of the twin comets, now, however, more than a million miles apart. Since that date, although many times due, they have not again been seen, and it is now generally believed that the disintegration of Biela's comet, which began by its division in 1846, has at length ended in its total dissipation.

Since the comet was lost, however, its attendant train of meteors has been found. Sciaparelli's discoveries regarding the association of meteors with comets, as shown in the case of the Leonides and Perseids, led Professor A. Herschel and others to predict that as Biela's comet was due to cross the Earth's path in the autumn of 1872, a display of shooting-stars in connection with it might be expected near the end of November, when the Earth itself would pass that way, and that such shooting-stars would attest their connection with the missing comet by appearing to radiate from the constellation Andromeda. No better test of the truth of a theory can be had than that of verified prediction, and the copious meteor-shower which occurred on the evening

of November 27th, 1872, amply satisfied this crucial test. For five hours shooting-stars fell in such numbers that from forty to fifty thousand of them were counted in England; and that these had no connection with the group of Leonides was proved by their totally different direction athwart the sky, the shower appearing to come, as had been predicted, from out the foot of Andromeda; and hence the name of Andromeds by which this meteor system is known.

A similar connection has been more or less satisfactorily made out between other meteoric streams and comets. That the association thus established is not accidental, but arises from their having something in common, is generally recognized by astronomers; many are, however, content to leave the matter here for the present, while others, as Professor Newton, consider it as proved that meteoric bodies follow in the track of comets, simply because they are the *disjecta membra* of those bodies, which have been, and are probably still being, driven off from the parent comet. In proof of this, they point to the fact that many comets are apparently growing smaller with each successive reappearance, while one —Biela's comet—would appear, as already stated, to have gone altogether to pieces.

The theory that would thus turn meteorites into fragments of comets is rejected by a few astronomers, who regard as untenable the view that meteorites

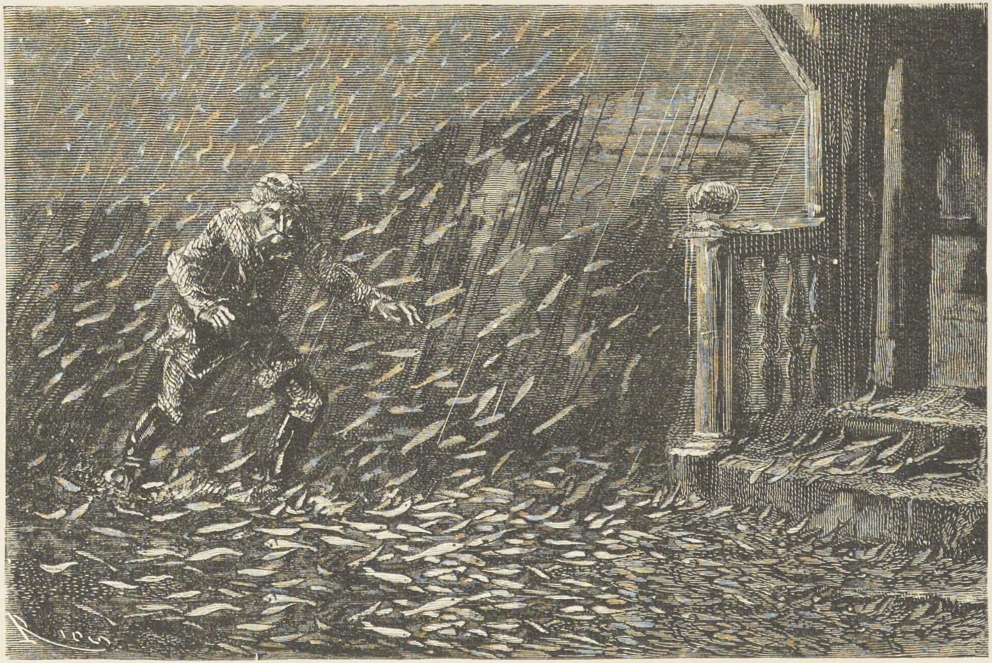
have any connection with shooting-stars, and these still cling to the old opinion that meteorites are bodies that have been driven from volcanoes on one or other of the smaller planetary bodies. The planet most in favour with the non-cometic school as that on which meteorites have originated is, strange to say, our own Earth. This theory supposes that at an early stage in the history of our planet there existed gigantic volcanoes, possessing sufficient explosive force to drive fragments of rock sufficiently high to carry them beyond the influence of terrestrial gravitation into interplanetary space, where as "pocket planets" they would revolve round the sun, crossing the Earth's track at each revolution, and entering our atmosphere when the Earth and the projectile met at the point of crossing. The preliminary difficulty of supposing a volcano capable of discharging projectiles with an initial velocity of at least six miles per second is one which will prevent most people from following the hypothesis of the terrestrial origin of meteorites further.

XXV.

REMARKABLE SHOWERS.

SHOWERS, although suggestive of water, are not confined to it. Lately it was recorded in the *Scotsman* newspaper that during a heavy storm of wind and rain near Airdrie a fall of live perches occurred, the fishes being picked up and taken home by the people on whom they were showered. Perches are found in the Monkland Canal, a mile from the scene of this animal shower, and still more abundantly in the reservoir at Caldercruix, six miles off. From one or other of these sources it is to be presumed the fish were caught up in a whirlwind and carried through the air to Airdrie.

Were this the first recorded instance of such a phenomenon, further inquiry might be necessary before giving it credence. There are, however, numerous other instances on record of small fishes, frogs, insects, and shells being taken up in storms and scattered over the ground. At Swansea in 1859, during a violent storm, a shower of small fishes, afterwards



SHOWER OF FISH IN TRANSYLVANIA.

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identified as young minnows and sticklebacks, descended over a limited area. They fell in such numbers on the roof of a house there, that a man holding a bucket at the end of one of the water-pipes had it quickly filled with water and fish in the proportion of two or three hundred of the latter to a bucketful of the former.

Young herring are too frequently used as manure around the Scottish coast; there are several instances, however, of these fishes being removed from their element and showered on the land by the agency of whirlwinds and waterspouts. In 1828, the ground on a farm three miles from Dingwall was found to be thus covered with herring fry. The people of Islay, two years later, had a similar visitation during a day of heavy rain, the fish in this case being found "perfectly fresh, and some of them alive." Wick has also had its shower of herrings, while in "Chambers's Book of Days" herring are said to have been carried during a gale of wind from the Firth of Forth and dropped as far inland as Loch Leven.

A few years ago, a shower of what was believed to be the spawn of a species of frog occurred in Kentucky. Frogs, however, are themselves known, in at least one authentic case, to have descended in a copious shower. The account of it was communicated to the French Academy in 1804, the event having taken place at Toulouse. It happened during a thunderstorm, with the result that roads and

fields were covered with young frogs, in some places three or four deep. Professor Pontus, who gave the account, actually saw the frogs on the cloaks of gentlemen who had travelled through the storm. Young frogs that have just left the water often make their appearance in immense numbers after a shower of rain, having been previously concealed beneath stones and grass to preserve themselves from the desiccating influence of sunshine, and their emergence from their hiding-places during rain has given rise to many unfounded stories of frog showers.

Large black insects are said to have descended with the snow in a great snowstorm at St. Petersburg in 1817; and Darwin tells of butterflies filling the air in such numbers, some miles off the coast of Patagonia, that the sailors cried out, "It is snowing butterflies." Although it has never been known to rain cats and dogs literally, a shower of rats is on record. During a vast migration of those rodents in Norway, they were on one occasion caught in a whirlwind and showered down in a neighbouring valley.

Other remarkable showers are those in which dust, sand, and ashes form the falling material. The cinnamon-coloured dust of the Sahara is thus carried aloft until it meets with aërial currents which carry it thousands of miles from its starting-place. This Saharan dust has been known to fall

in showers on the streets of Lyons, and vessels sailing along the west coast of Africa often have their decks covered with it. According to Dr. Geikie, Daubrée recognized some of the Saharan sand which had fallen on the Canary Islands. The same investigator states that four days after the great fire of Chicago, ashes, supposed to be from it, fell on the Azores. Showers of fine dust fell on the east coast of Sweden in 1875, and microscopic examination proved it to be the product of the Icelandic eruptions of that year. Those same volcanoes have even made their influence felt in the north of Scotland; for during the great eruption of 1783 the fine dust ejected not only filled the entire atmosphere of Iceland for several months, but fell in sufficient quantity in Caithness, six hundred miles away, to destroy the crops there; hence that year, says Dr. A. Geikie, is still spoken of as "the year of the ashes."

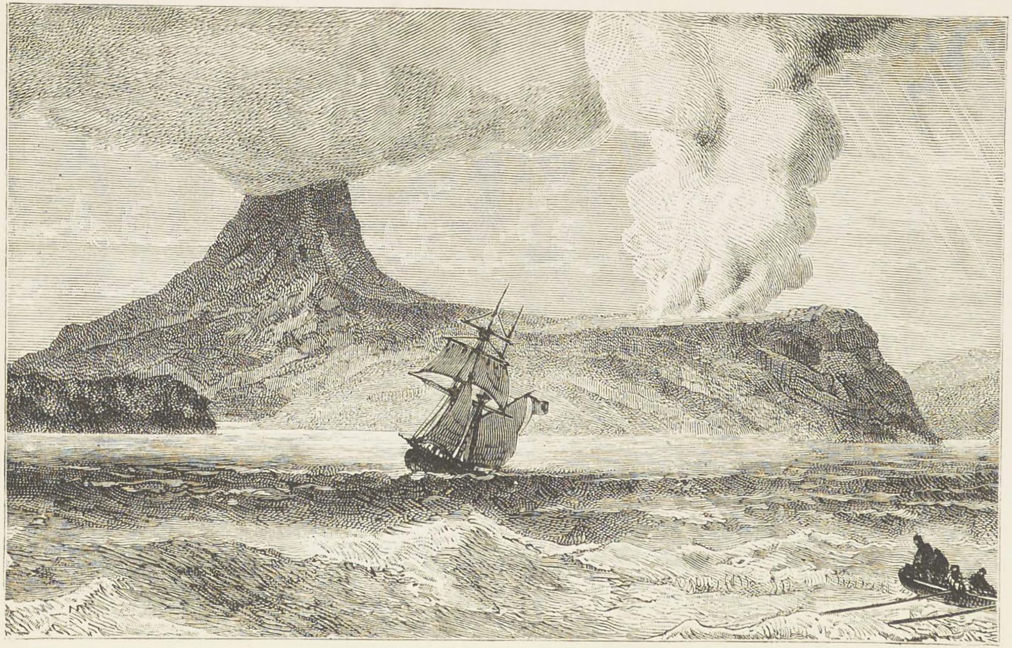
The records of destructive volcanic showers are only too numerous. For eight successive days and nights showers of sand, pumice, and lapilli fell from Vesuvius on Pompeii and Herculaneum; by which time these cities were so effectually buried that it is only of late years, and after the lapse of eighteen centuries, that they have been partially uncovered. During the Vesuvian eruption of 1822 the showers of dust produced in Naples "a darkness that might be felt." Mr. Whymper, standing once on the summit of Chimborazo, witnessed an eruption of Coto-

paxi, and although more than fifty miles away the fine dust fell all around him. He estimated that in this comparatively trifling eruption about two million tons of dust must have been thus showered abroad. During another eruption, in 1877, this volcano threw into the atmosphere such enormous quantities of dust and ashes that in an hour and a half Quito, thirty-three miles distant, passed from a bright morning into a dim twilight, which gradually faded into such dense darkness that the hand placed in front of the eyes could not be seen. A similar darkness fell over a circular area about seventy miles in diameter during the tremendous eruption of Coseguina in Nicaragua in the year 1835, and the dust of this volcano fell four days after at Kingston in Jamaica, a distance of seven hundred miles. The showers of volcanic matter ejected from Sumbawa during the eruption of 1815 are said to have fallen over an area of nearly a million square miles, and their amount has been estimated at about fifty cubic miles of material—a quantity equal to about one hundred and eighty-five mountains like Vesuvius. Vast showers of pumice sometimes occur ; and as this volcanic rock floats for a long time on water, it is occasionally met with in enormous quantities at sea. In 1878 it was reported as covering the sea to such an extent in the neighbourhood of the Solomon Islands that it took ships three days to force their way through it.

Probably the greatest shower of volcanic ashes and dust on record is that which took place during the terrible eruption of Krakatoa in August 1884. It darkened the air over an immense extent of country for nearly two days. The darkness at times was so intense that at noon of August 27 the crew of a ship sailing at least thirty miles from Krakatoa had to grope their way on deck, and were quite unable to see each other; meanwhile there was a constant downpour of mud, sand, and other volcanic products. At Batavia, according to the *Straits Times*, on the same day, ashes fell so copiously that by mid-day everything was enveloped in thick darkness. "From the lack of sunlight the temperature fell several degrees, and people shivered with cold." When the atmosphere cleared a little, the whole of Batavia was seen to be covered with white ashes, thus giving this tropical possession of Holland the aspect of a Dutch winter scene. It was only the heavier particles, however, that fell so near the scene of the eruption. The finer dust and volcanic vapours were borne aloft into the upper regions of the atmosphere, and were thence spread by aërial currents over the world. For proof of this widespread distribution of the dust of Krakatoa, Mr. Lockyer and others point to the remarkable sunrises and sunsets that have been observed of late over so wide an area.

It is a remarkable fact that the light which makes

all things visible is itself invisible. The ray of sunshine let into a darkened room is not itself seen, but only the motes illuminated by it, and if these be removed the track of the ray ceases to be visible. If, therefore, the air were absolutely free of matter foreign to it, there would be an end to all variety of chromatic effects in our atmosphere. The air, however, is not pure; on the contrary, it is more or less loaded with foreign particles. Invisible themselves, the solar rays illumine this floating matter, and thus the heavens are suffused with light. Tyndall has shown that the larger particles scatter rays of every colour, that is white light; while the finest, such as those present in the clearest skies, scatter only the rays from the blue end of the spectrum. Hence it is that clouds, which consist of comparatively large aqueous particles, are white, while a clear sky is blue. These minute motes in the air are most numerous in the lower strata of the atmosphere, and the more the sun sinks towards setting the greater are the number of these suspended particles encountered by its rays. The effect of this is, that the white light of the sun is sifted and broken up, the rays of small wave length being stopped. The violet and blue rays, as being the shortest, are thus the first to disappear, and the light which reaches us appears of an orange colour. The yellow tints are next cut off, leaving to us the red glow of sunset. At sunrise the same phenomena occur, only in reverse order. The beau-



ISLAND OF KRAKATOA IN MAY 1883.

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tiful chromatic effects witnessed at sunrise and sunset are thus due to the action on sunlight of the foreign particles suspended in the air, the effect varying with the amount, and probably also to some extent with the nature, of those extraneous particles.

The late extraordinary sunsets were first observed at the Seychelles and Mauritius the day after the great eruption of Krakatoa, and they were there unhesitatingly attributed by the well-known meteorologist Dr. Meldrum to the presence of finely-divided volcanic dust in the atmosphere. Taking the dates at which these abnormal sunsets and sunrises, green suns and blue suns, were first observed in different parts of the world, Mr. Lockyer has shown how well the time and character of the phenomena agree with what might have been expected on the theory that the appearances were due to the gradual spread of the clouds of volcanic dust from Krakatoa through the Earth's atmosphere. If such be the true theory, it ought to obtain some verification from an examination of the dust found in recent falls of snow, and Mr. Lockyer shows in *Nature* that such evidence has been obtained. "Material," he says, "brought down by rain in Holland and snow in Spain, has, on microscopic examination, proved to be identical with actual products of the eruption brought from Krakatoa in the ordinary manner." In other words, crystals of hypersthene, pyroxene, magnetic iron, and volcanic glass, have been

found in newly-fallen snow at Madrid, and these have also been obtained in the analysis of volcanic ashes lately brought from the scene of the Java eruption. A counter theory to that of Mr. Lockyer has been put forward by Mr. Ranyard, who thinks it more probable that the Earth has encountered a cloud of meteoric dust in space, and that to the slow fall of this cosmic material through our atmosphere the late abnormal sunsets are to be attributed. The known facts, however, seem to point to Krakatoa rather than to space, and to the telluric rather than to the cosmic theory as the true one. There need be little doubt, therefore, that to the eruption which wrought such havoc to life and property in Java we owe those splendid chromatic effects at sunset and sunrise which have of late astonished the world.

XXVI.

THE ACTION OF THE TIDES.

THE cause of the tides was one of those things which the ancients regarded as past finding out, and hence they spoke of the tides as "the tomb of human curiosity." The singular connection between the diurnal motion of the Moon and the ebb and flow of the tide did not, indeed, long escape the notice of seafaring nations; but whether the Moon influenced the tides or the tides the Moon, or whether the seeming connection was but a chance coincidence, remained a mystery, until Newton, by his discovery of the law of gravitation, supplied the key to this as well as to many other physical enigmas.

The tides are the offspring of lunar and solar attraction. Speaking roughly, the Moon may be said to draw the water away from the Earth on the side nearest it, and at the same time to draw the Earth away from the water on the side most remote, the effect in both cases being a swelling of the sea on opposite sides of the globe, with corresponding

aqueous depressions between; in other words, the ebb and flow of the tide. The Sun is so much further away than the Moon, that although enormously bulkier, its tide-producing force is only about two-fifths that of the Earth's satellite. When these greater and lesser lights pull together, as they do at new and full moon, the ebb and flow are each considerably increased, producing what are known as *spring* tides. When, however, they act against each other—that is, when the solar low water coincides with the lunar high water, and *vice versa*, as happens when the Moon is in her first and third quarters—then ebb and flow are correspondingly lessened, and *neap* tides are the result. The Moon, in her monthly revolution, does not keep at a uniform distance from the Earth, at one time approaching, in her elliptic orbit, twenty-six thousand miles nearer us than at another. The nearer her approach, the greater, of course, is her tide-producing force. The Sun, also, is nearer the Earth in our winter than in summer, and consequently the solar tide is stronger in January than in July.

A considerable variety of astronomical data, it will thus be seen, enters into tidal calculations. The result is, that the highest tides are those produced by the largest possible combination of favouring circumstances; as, for example, when the Sun and Moon both pull together at a time when each orb is in that part of its path nearest to the Earth. During

the year 1881 a near approach to such a conjunction of circumstances occurred towards the end of February, when the resulting high tides caused destructive floods on certain parts of the British coast. Nearly similar coincidences occurred at the end of August of the same year, and also at the beginning of December, on both occasions causing unusually high tides. Happily, however, the prevalence of light winds prevented a recurrence of the disastrous floods of February 19th and 20th. Had only a moderate gale been blowing in the proper direction, the inundation of considerable tracts of low-lying country would have been inevitable.

Seeing that the tides are primarily due to the action of forces outside our Earth, it might have been supposed that the result would have been tolerably uniform throughout the world of waters. This, however, is very far from being the case, some seas being almost tideless, while in others the tide varies from seven to seventy feet on different parts of the same coast. The explanation of this lies in the fact that the tides are profoundly influenced by such local circumstances as the outline of the coast, the varying depth of water, and the force and direction of the wind. Thus, according to Lyell, the highest tides on any coast occur in narrow channels, bays, and estuaries; the lowest in intervening tracts, where the land is prominent. In the estuary of the Thames the ordinary spring tides reach a height of eighteen

feet, and in the Wash at Lynn Regis twenty-six feet; while in the projecting coast between they diminish to seven or eight feet. The highest tides of all occur in funnel-shaped estuaries which open in the direct line of the advancing tidal wave; such as the Bristol Channel, where the tide has been known to rise upwards of seventy feet; and the Bay of Fundy in Nova Scotia, where it sometimes exceeds one hundred feet.

In the open ocean there is no perceptible tidal current, the water merely rising and falling. Its apparent onward movement is no more real than is that of the heads of corn in a field moved by the wind, it being in both cases only the motion that is transmitted. In confined channels and river estuaries, however, it is the water itself that is driven forward, and the tide becomes a stream which travels more or less quickly according to the nature of the obstacles encountered. It thus happens that within a comparatively short distance there may be a considerable number of co-existent high tides, with corresponding ebbs between. In the estuary of the Amazon, for example, there are said to be no fewer than seven high tides, at one and the same time, within a length of six hundred miles; while in the comparatively small estuary of the Thames the high water at the Nore does not reach London Bridge till twelve hours later, by which time there is another full tide at the Nore. In all tidal rivers the ebb is

a much slower affair than the flow, and in the Severn especially the one follows closely on the heels of the other—the tidal wave, like a wall of water, rushing suddenly up the river, and forming along the sides of the channel a dangerous surf known as the "bore." The Bay of Fundy, however, affords the grandest examples of this dangerous phenomenon.

On oceanic islands the rise and fall of the tide is inconsiderable, rarely exceeding three feet. So also lakes and inland seas are for the most part tideless, being cut off from the main tidal movement of the ocean, and being in general too small to have tides of their own. This, however, does not apply to the Mediterranean, which, with its eight hundred thousand square miles, is sufficiently large to have tides generated through the action on its surface of lunar and solar attraction. Its tides, however, are as a rule too insignificant to excite ordinary observation, although in the Strait of Messina there is an ebb and flow of about two feet, while at Venice the tide reaches the respectable height of five feet.

In some parts of the ocean tides of exactly opposite kinds, and coming from different quarters, meet, with the effect of extinguishing each other. Thus at Tonquin there is no perceptible tide, owing to an ebb approaching from the China seas extinguishing a flow advancing from the Indian Ocean. The same occurs nearer home, in the German Ocean, at a point a little north of the Strait of Dover, when

low water transmitted round the Pentland Firth meets and neutralizes high water from the English Channel. These two colliding tides are parts of the great tidal wave which, impinging on the south-western coast of Britain, travels all round it in eighteen hours. In the absence of other proof, the insular character of Britain might be inferred from the meeting of the two branches of this great wave; and it is mainly on such an inference, drawn from tidal observations, that Greenland is now believed to be an island. The staff of the late Arctic Expedition, when in winter quarters, discovered a new type of tide, not to be confounded either with that from Baffin Bay or that from Behring Strait. It could only, therefore, have come round from the east coast by a northern route; and hence they inferred the insular character of Greenland.

Owing to the numerous complications—astronomical, geographical, and meteorological—which obscure the laws that govern the tides, it is not surprising that physicists as distinguished as Sir William Thomson should have considerable difficulty—as he lately stated—in answering the question, What is a tide? Whether defined or not, however, the tides remain an important factor in seafaring business, and Sir William Thomson has done good service to science and navigation by the perfection to which he has brought his tide-predicting machine. After certain data regarding the tides of a port have been found

by means of his tide-gauge and harmonic analyzer, the new instrument can not only predict the time of low and high water, but the position of the water level at any instant of any day in the year. By simply turning a handle, the year's tide curve is run off in little more than twenty minutes.

With the fuller acquaintance with tidal details which such an instrument can give, man ought to be better able to turn the tides to useful account. At present their exhaustless energy is chiefly spent in breaking down and transporting rocks, although they also perform useful work in the formation and keeping open of estuaries. In a tideless sea, says Lyell, "it is almost impossible to prevent a bar at a river's mouth from silting up;" but with the rush of ebbing water in a tidal river the mud and other *débris* which would otherwise choke its channel are carried out to sea. The opinion has lately been gaining ground that means will yet be found of converting the tidal energy into electricity, which, transmitted to a distance, could be used in the supply of cities and towns with light, heat, and motive power. Recently Professor Sylvanus Thompson calculated that if only a tenth part of the energy thus running to waste in the channel of the Severn could be converted into electricity and stored in Faure's batteries, it would be sufficient to light up every city in the kingdom, while another tenth would suffice to keep every British loom, spindle, and

axle in motion. The difficulty, however, lies in harnessing the tides. To effect this, Mr. Arthur Oates, in a paper recently read before the Society of Engineers, advocates the construction of tidal dams. A suitable tidal inlet being selected, he would construct a weir across its entrance, so as to exclude the sea until near the time of high tide, when, on being admitted, the fall of water would be utilized by suitable machines, which he calls "motors." When full, the water would be retained in the enclosure until the time of low tide outside, when its escape seawards would be similarly utilized. That certain parts of our coasts would lend themselves more readily than others to the construction of such weirs, and that by their means valuable motive power could be obtained, is undeniable. That this power could be had at a cheaper rate, or even as cheaply from the tides as from coal, is, however, by no means clear. The writer of the paper himself has evidently considerable doubts on this point, as he suggests that the weir might also be used as a promenade, or as a bridge connecting the opposite sides of an inlet, and that thus a revenue might be derived from it independently of its main purpose. While coal continues abundant and cheap, tidal dams will probably remain a dream of the engineer; a time, however, is certainly coming when the scarcity of fuel will lead to the utilization of this exhaustless but hitherto wasted energy, and Britain, which has been fortunate

in the wide area of its coalfields, will then be equally fortunate in the enormous extent and indented character of its coast.

The tides form one of the existing agencies of geological change. The land margin everywhere is being wasted by their flow, while the disintegrated material thus produced is carried seaward in their ebb to be scattered by currents over the sea bottom, there to form the strata of future lands. Other agencies, such as rivers, rain, and ice, co-operate with the tides in rubbing down the land surface and in carrying the eroded material to the sea. If sufficient time be allowed them, these agencies, acting just as they are doing at the present day, seem perfectly competent, as Sir Charles Lyell maintained, to have produced all the stratified rocks with which the geologist has to do. The time demanded by the uniformitarian geologist, however, extends to hundreds of millions of years, and at the present rate of change probably nothing else would suffice. Taking the mean level of Europe above the water to be six hundred feet, Dr. A. Geikie estimates that, at the present rate of denudation, it would take three and a half million years to wear it down to sea-level. As new continents are built up entirely of the cast-off material of former ones, the work of reconstruction must necessarily be as slow as that of demolition; and some idea may thus be formed of the enormous time it would take for the deposition

of, say, twenty miles' thickness of stratified rocks. Yet this, according to Professor Williamson, is the estimated amount of the strata deposited on the ocean bed up to the close of the Silurian period—an age when as yet the world was comparatively young, and only the lower forms of animal life had come into existence.

By calculations founded on the internal heat of the Earth, and from other data, physicists have been able to form a rough estimate of the world's age, and these agree in greatly curtailing the time at the disposal of the geologist. Professors Thomson and Tait, for example, maintain that the world cannot have been cool enough to permit of the existence of life on its surface more than fifteen million years ago. "Granted," says Professor Tait in a recent work, "that physical laws have remained as they are now, and that we know of all the physical laws which have been operating during that time, we cannot give more scope for their [geologists'] speculations than about ten or at most fifteen million years." If all past geological phenomena are to be explained by a reference to causes now in operation, it is plain that, with the limited time granted them by the physicist, geologists must have recourse to the view that the causes now in operation were much more potent in the past than they are at present. The latest investigations seem to show that, with the tides at least, this has probably been the case.

These, as already stated, are produced by the attraction of the Moon ; and were the Moon brought nearer the Earth, its attractive power, and consequently the height of the tides, would be correspondingly increased. Now, according to Professor Ball in a remarkable lecture delivered lately at Birmingham, the recent researches of several eminent physicists, and especially of Mr. G. H. Darwin, son of the eminent naturalist, go to show that the Moon is circling round the Earth in an ever-widening orbit, and that consequently the Moon in past ages must have been much nearer the Earth than it is now. The difference in the lunar orbit during a thousand years is trifling, but in the course of millions of years the difference becomes much more appreciable—so much so, indeed, that according to Mr. G. H. Darwin's theory, the Moon, not less than fifty-four million years ago, must have been so close to the Earth that the two bodies were almost touching. At that remote period the Moon must have revolved round the Earth in about three hours, instead of twenty-seven days as at present; but as time advanced its orbit widened, and its month—that is, the time it took to perform the circuit—grew longer.

What may have been the distance of the Moon from the Earth at any particular geological period, it is impossible to tell with any approach to accuracy; certain it is, however, if Mr. Darwin's mathematical reasoning be correct—and we are not aware of

its ever having been called in question—the Moon's distance must have been less than the present two hundred and forty thousand miles. Professor Ball supposes that at the dawn of life on the Earth, when palæozoic rocks many miles in thickness were being deposited, the Moon may possibly have been not more than a sixth of its present distance from the Earth. In that case its tidal efficacy would be two hundred and sixteen times greater than it is now; and taking three feet as the average height of the tides at the present day, we have a palæozoic tide at least six hundred and forty-eight feet high. The power of such an aqueous engine in grinding down the land surfaces subject to its ebb and flow would be immense, altogether dwarfing, it may be safely presumed, the combined effects of all the denuding agencies at present in operation.

The geological action of the tides, puny as these now are in comparison with those of primeval times, is patent to any one acquainted with the sea coast. Not so manifest, although equally certain, is the action of the tides in increasing the length of the day. Although the Moon sets the tides agoing, it is with energy supplied by the Earth's rotation that they do their work. Terrestrial energy is being thus constantly withdrawn, and as there is no means of restoring it or of making good the loss, the energy of the Earth's rotation is slowly diminishing. The diurnal rotation of the Earth on its axis is being thus

retarded, and consequently the day is being lengthened. As in the case of the increasing distance of the Moon from the Earth, the lengthening of the day proceeds too slowly to be perceptible in the lifetime even of a Methuselah. In a thousand years it only amounts to the fraction of a second, although after the lapse of millions of years it becomes sufficiently apparent. When possessed of all its pristine energy, and before tides had arisen to cause friction and consequent retardation, the Earth, according to Mr. Darwin's calculation, performed its daily rotation in about three hours. That the day could not have been much shorter than this is certain, as a slightly higher speed would have led to the Earth's disruption. This was the time when the Moon is supposed to have been circling close to the Earth, performing its journey round the parent planet in the same period of three hours. With the beginning of the tides the retardation in the rate of the Earth's rotation commenced, and this has proceeded until what was at first accomplished in three hours now takes twenty-four.

So long as the tides endure, this lengthening of the day will inevitably proceed; and if the universe should last long enough, those lunar tides will continue until a time arrive when the day will be of equal length with the month; that is, when the Earth will take as long to rotate once on its axis as the Moon will to move round its orbit. When this

happens—and, according to Mr. Darwin, it will take place when the day has been lengthened out to about fourteen hundred and forty hours—the Earth will have been brought by tidal friction to turn the same portion of its surface at all times to the Moon. Here it will always be full tide; in other words, the tidal ebb and flow will have been arrested. Instead of lagging behind, and thus acting as a drag on the Earth's rotation, the tide wave will then rotate with the Earth, and retardation will cease. This is exactly what has already happened to the Moon. Its seas of molten lava were at one time the scene of enormous tidal action, due to the attractive influence of the Earth. The friction thus produced gradually reduced the rate of its rotation on its axis until that became identical with its orbital motion, with the effect of causing the Moon to turn the same portion of its surface constantly to the Earth. Nobody has ever seen "the other side of the Moon;" but it was only lately that Helmholtz satisfactorily explained the phenomenon by referring it to tidal friction.

That the goal to which our Earth is thus hastening should have been reached so much earlier by the Moon is not surprising when it is remembered that the Earth is eighty times as heavy as its satellite, and must, therefore, have given rise to enormously higher tides in the Moon than any which the relatively insignificant satellite could produce on our planet. Were Earth and Moon, after the suppression of

lunar tides, left to themselves, they would go on rotating and revolving in identical periods of fourteen hundred and forty hours. The Sun, however, exercises a disturbing influence on the Earth, producing the so-called solar tides. Their action would again tend to retard the Earth's rotation, and so still further to lengthen the day. The result would be that at last the Moon would revolve more quickly round the Earth than the latter would on its own axis; that is, the day would become longer than the month. Such a condition of things was, until lately, not known to occur in the solar system; recently, however, it was found by Professor Asaph Hall that one of the lately discovered satellites of Mars revolved round that planet in less time than did Mars on its own axis—the latter rotating once in twenty-four hours, while the satellite performed the journey round Mars in seven. This unique state of matters is due, according to Professor Ball, to the action of solar tides, and it is a condition to which the Earth and Moon may yet be brought by tidal friction.

XXVII.

AMERICAN TORNADOES.

THE birth-place of the bulk of British storms is America, from whence news of their coming hither is usually heralded some days in advance. The United States, however, is large enough to have storms which begin and end in its own territory; and among these, happily for us, are the tornadoes, which, though limited in the area of their operation, are among the most destructive of aërial agencies. Those fierce whirlwinds are not confined to the New World, although certain portions of the United States are among the most tornado-swept tracts of the globe. Lately, this region, which includes the States of Iowa, Illinois, Missouri, and Kansas, was visited by a series of these storms, which seem to have equalled in destructiveness most of their predecessors. Half the town of Grinnell in Iowa is said to have been swept away and a hundred of its inhabitants killed, trains were blown off the lines, river steamers sunk, numerous lives lost, and prop-

erty destroyed to the value of several millions of dollars. Towns in those tornado-vexed States are still few and far between, nor as yet have they attained the dimensions of great cities. Should they grow, however, with the growth of population which marks other parts of the United States, the danger to life and property would be greatly increased, owing to the greater chance of coming in the way of these fierce tornadoes. What might then happen may be surmised from the destruction occasionally wrought by those storms in thickly-peopled China. Thus the tornado which passed over Canton in April 1878, and the width of whose path was only six hundred feet, caused the death of no fewer than six thousand people during the three or four minutes it lasted.

There are few years not marked in one or other of the States of the Union by the occurrence of destructive tornadoes; and the records which have been kept of the more remarkable of these supply a sufficiently vivid picture of what a tornado is like, if not of what it is. The Irving tornado of 1879 was described by those who saw it approaching as resembling pillars of cloud of inky blackness, "all rolling, dashing and clashing with each other, as if engaged in a furious battle." An eye-witness of the Wisconsin tornado of 1878 stated that he saw a cloud approaching which reached to the ground; the lower part so black that nothing could be seen

within it, while at a height of two to three hundred feet the air appeared to be filled "with trees, rails, boards, hay, leaves, and other *débris*, all rapidly whirling and shooting upward and downward in terrible commotion."

Sergeant Glenn of the United States Signal Service thus describes the formation and career of the great Dakota tornado of August 28th, 1884: "Imagine," he says, "a vast treeless plain, void of hill or dale, and a sultry atmosphere beneath a sky unobscured save by small drifting cumulus clouds, which have piled up in a woolly mass in the north, as though checked by some invisible barrier separating them from the horizon by a strip of clear sky. Then there is a rapid and confused whirling: the centre of the mass drops down bowl-shaped, and appears as if making futile efforts to touch the earth. At the same time a conical cloud of dust is seen to accumulate on the ground and acquire a rotatory motion. With the swiftness of thought, the upper cloud drops a considerable distance downward, and spins out a white ribbon-like line towards the ground. The connection between the earth and the cloud being established, it remains stationary for a moment, apparently gathering strength before starting on its career of destruction. Then it moves rapidly over the plain, destroying everything in its path. A number of cattle and horses were taken from a herd, lifted bodily high in the air, and

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churned together in a living mass; three steers and four horses were killed, and more were wounded. Most of the beasts appeared to have their lower jaws dislocated. The tornado crossed the Dakota river, taking up the water so suddenly as to leave the bottom exposed for an instant. The water was carried to a great height, and was not seen to fall; but heavy rain with some hail occurred twelve or more miles to one side of the track."

They are in most cases described as forming funnel-shaped clouds of ominous darkness, and as moving along with a characteristic swaying and halting motion. Their rate of forward progress varies considerably, in some cases not exceeding twelve miles an hour, in others reaching as high as twenty-six miles. While the storm as a whole is thus moving forward at a leisurely rate, the air within the tornado is spinning round at enormously greater speed, the velocity increasing the nearer the wind is to the centre of the whirl. It has been calculated, from the wind pressure required to move certain bodies that have been known to be caught up in those whirlwinds, that the air within must have been moving with a velocity of over one hundred miles an hour.

Appalling as the appearance of those moving cloud-columns must be, they are rendered still more terrific by the noise which accompanies them. A spectator compared the noise of one of the Kansas

tornadoes of 1879 to the roaring and rushing of a thousand locomotives; that of Chester County, Pennsylvania, was said to have been accompanied by a continuous roar like that of thunder. The sound made by the conflict of winds in another drowned, it is said, all other sounds. A man could stand by his house as it was shivered to pieces and not hear the noise of its breaking, while the tornado's roar was heard at a distance of sixty miles.

Most appalling of all is the destruction wrought by these storms, which probably afford the most striking examples known of the terrible force of air when moving with sufficient rapidity. The Pennsylvania tornado of 1877 blew down buildings, twisted thick oak-trees in two, tore up others by the root, and whirled them aloft. During the Ohio tornado of 1842, large buildings were lifted entirely from their foundations, carried some distance through the air, and then dashed to pieces, some of the fragments being carried seven or eight miles. In that of Mount Carmel, Illinois, in 1877, the spire of a Methodist church was transported fifteen miles, having been kept suspended in the air by the strength of the ascending current for about twenty minutes. So also in the Wisconsin tornado of 1878, the school-house was destroyed, and the teacher carried some distance off, while the school-register was picked up next day sixty miles away. The path of another tornado was said to have been marked as if

gangs of navvies had dug it up with shovels for the road-bed of some giant railway. In this instance the largest trees, according to Professor Parker, were twisted off close to the ground like pipe stems, or taken up by the roots and carried for hundreds of yards, then dashed to the ground and splintered into firewood. Hundreds of lives have been lost during recent years through these tornadoes, although there are many remarkable stories told of both men and cattle being borne aloft for considerable distances, and then deposited safely on the ground. That more lives have not been sacrificed is due to the fact that in the region where tornadoes are most frequent the houses are generally provided with underground cellars, into which the inhabitants retire when one of these whirlwinds is seen approaching. While life and such movable property as money and other valuables may thus be secured under ground, it is hopeless to attempt to raise buildings strong enough to encounter the eddying blasts.

Powerful as the tornado is, the area within which any single one operates is very limited. That which lately passed through the town of Grinnell had a breadth of about twelve hundred feet, while some of the most disastrous on record have not had more than a third of that width. The distance they travel over is also comparatively little; that of Chester County, Pennsylvania, for example, having

run a course of only twenty-two miles. They may thus be described as aërial torrents which rush along a narrow invisible channel in endless whirls and eddies, soon to lose themselves, however, in the great atmospheric ocean. In many cases they are accompanied by torrents of rain, caused by the condensation of the aqueous vapour carried up in their ascending currents. Sometimes, also, the weight of moisture which accumulates in the tornado-cloud becomes excessive, and the water breaks through and falls in a mass, causing what is known in the States as a "cloud-burst." The power of these *water-falls* is enormous. Thus Espy states that after the great Pennsylvania tornado of 1838 he found holes dug out by the water that had been thus shot down, which measured thirty feet in diameter, and from three to six feet deep. When the vapour-laden currents of the tornado ascend high enough to reach the region of frost, hailstones are formed; and these falling, are caught up by the whirlwind before reaching the ground, to be again thrown up to an icy height. This may be repeated over and over again, the hailstone growing larger each time by a fresh coating of snow or ice. As many as thirteen layers have thus been observed in large hailstones; and a shower of such stones, each about the size of a pigeon's egg, forms an important addition to the terrors of the tornado.

What, it may be asked, are the conditions which

give rise to tornadoes? There are instances on record of whirlwinds—which resemble tornadoes in everything but their intensity—having been formed over volcanoes, and even over extensive fires like those of the Carolina cane-brakes. In these cases it is supposed that the heated lower air, being lighter than that immediately above it, gives rise to a disturbance of atmospheric equilibrium, resulting in the uprushing of the heated air and the formation of a whirlwind. Wherever the air is exceptionally warm and moist, and where, consequently, the temperature and moisture diminish with height at an unusually rapid rate, there the conditions exist for the production of that vertical disturbance in the equilibrium of the atmosphere which, according to the best authorities, gives origin to the tornado. On this theory the fact that these storms never occur at night nor in winter, and seldom even in cloudy weather, can readily be explained.

The tornado, as already stated, is merely an intense form of whirlwind, and is therefore essentially the same in kind with the dust-storms of India and Africa, and the water-spouts and white-squalls of tropical seas. In the dust-storm, the hot air, sweeping along the ground, at last ascends in numerous columns, which carry with them the evidence of their surface-origin in the dust and sand which they bear aloft. Thus rendered visible, they are seen from afar. Sir Samuel Baker states that he has seen

them in the deserts of Nubia, "travelling and waltzing in various directions, at the fitful choice of each whirlwind;"—a vagrancy which the Arabs regard as undoubted proof "of their independent and diabolical character." These whirlwinds of dust as they pass envelop everything in midnight darkness.

Waterspouts are simply whirlwinds over the surface of sea or lake, rendered visible, not by the descent of moisture from the clouds, but by the condensation of the vapour in the ascending column of air. The whirlwind in the desert can only stir up the sand; on the ocean it stirs up the waters, which are thrown into a state of violent agitation along its path. It does not, however, as is popularly supposed, suck up the water of the sea; that poured down on the decks of vessels from waterspouts being, according to Mr. Buchan, "either wholly fresh or only slightly brackish." They are one of the perils by sea which, fortunately, sailors seldom encounter.

White-squalls are invisible waterspouts occurring in regions where the air is too dry to furnish the necessary cloud. The one end of them, however, is seen in a patch of white cloud high up in the air, while their lower termination is marked by strong commotion on the surface of the sea. There is no doubt that between the white patch of cloud above and the troubled waters beneath there stretches an

invisible aërial column of swiftly gyrating air; the destructive power of which, to quote from a recent writer in *Nature*, "is occasionally so dreadful that it has been known to strip a ship of every sail and mast in a few seconds, and leave it lying a helpless log amidst the tremendous seas which follow it."

The Americans have led the way in the investigation of tornadoes and other allied phenomena, and much of our knowledge on this subject is due to the labours of Professor Ferrel, the results of which have recently appeared in his work on "Cyclones, Tornadoes, and Waterspouts."

XXVIII.

THE RISE OF THE NILE.

At a time when the source of the Nile was a greater mystery than it is now, the Egyptians believed that it took its rise in Paradise. Nor is this surprising, in view of the benefits conferred on their country by its magnificent river. Egypt is the gift of the Nile. The now fertile delta was, ages ago, in all probability an arm of the sea, which has since been reclaimed from the Mediterranean by the gradual deposit of river alluvium; while the rest of the Nile valley differs from the desert which stretches on either side of it from the Atlantic to the Red Sea, simply by reason of the fertilizing effect of this solitary thread of water which thus cleaves the great Sahara in two.

The Nile is the name given by the Egyptians, not to the river itself, but to its most remarkable phenomenon—the annual inundation. The supernatural character of the beneficent flood to which

he owes his daily bread has never been doubted by the superstitious Egyptian; and in this case, it must be confessed, facts were apparently in his favour. Rains and snows, which swell other rivers, are totally unknown in Egypt. There is scarcely even a drop of dew; yet about the middle of June this anomalous river, with practically undeviating regularity, begins to rise, and continues rising till the middle of October, when it reaches its maximum height. Thus, when other rivers are at their lowest, the Nile is in high flood, and that in spite of the fact that its whole Egyptian course is through a scorching desert which would lick up the waters of any ordinary stream.

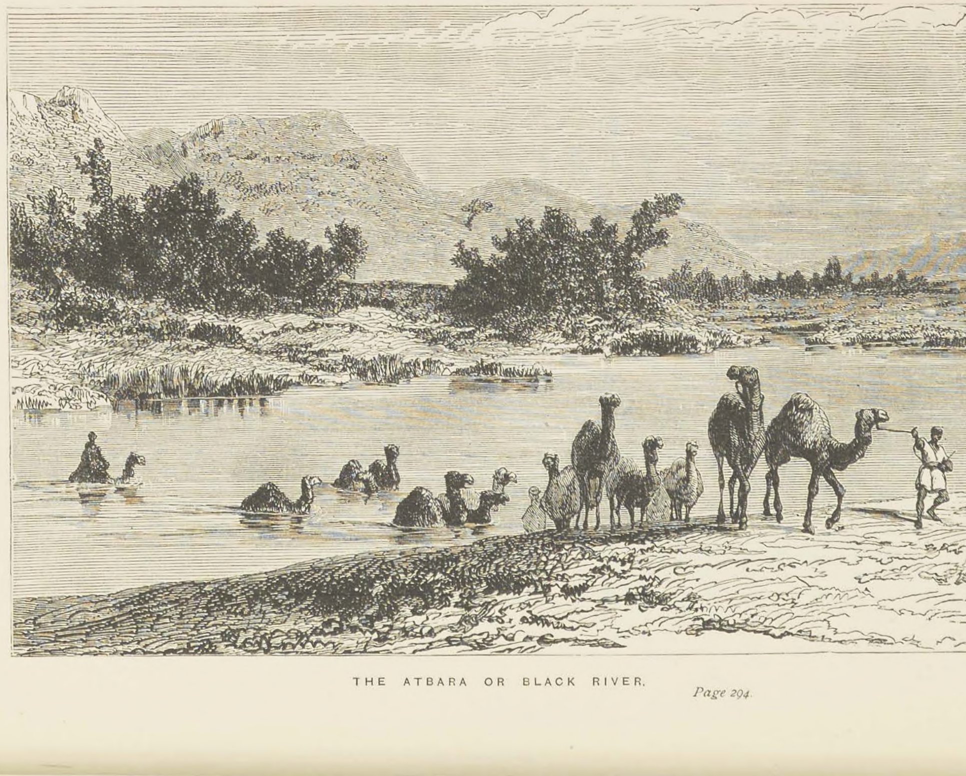
The night of June 17th is known throughout Egypt as the "Night of the Drop," the popular belief being that a miraculous drop then falls into the Nile, causing it to rise; and the modern Egyptians, in large numbers, spend this particular evening on the banks of what they still call "the most holy river."

In former times when the rising of the Nile was delayed even for a single day, the circumstance was attributed to the anger of the river god; to appease whom the loveliest maiden that could be found was taken, and, after being richly dressed, was drowned in its waters. The Mohammedan caliphs put an end to this barbarous practice; and they and their successors have since

contented themselves, when the river shows tardiness in rising, with throwing a letter into the stream, commanding the waters to rise, if such be the will of God.

Modern geographical research has removed the mystery surrounding the question of the source both of the great river of Egypt and of its annual flood. That the Nile, which, unlike every other river in the world, flows for the last fifteen hundred miles of its course without receiving a single tributary, is not wholly dried up, for at least part of the year, by the burning sun and hot sands of the Nubian desert, is due to the perennial flow of water from the magnificent lakes of Central Africa which lie at its source; while its annual inundation is caused by the flooding of its Abyssinian tributaries during the rainy season.

From September to May the mountainous Abyssinia is as rainless as Egypt; and during that season its rivers—the Atbara and the Blue Nile, with their numerous branches—are for the most part dried up. The Atbara or Black River, to which the inundation of the Nile is mainly due, although fed by at least three perennially flowing tributaries, is throughout the last one hundred and fifty miles of its course perfectly dry from March to June. The life of this river, according to Sir Samuel Baker, is preserved in deep pools which occur at intervals of a few miles.



THE ATBARA OR BLACK RIVER.

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In these narrow asylums, he says, "crocodiles, hippopotamuses, fish, and large turtles, are crowded in extraordinary numbers, until the commencement of the rains in Abyssinia once more sets them at liberty."

The rain-storms which prevail in that country for four months of the year seem to be terrific. During their continuance, according to the distinguished traveller already mentioned, "every ravine becomes a raging torrent, trees are rooted up by the mountain streams swollen above their banks, and the Atbara becomes a vast river, bringing down with an overwhelming current the total drainage of four large rivers, tributaries of it, in addition to its own original volume." The Blue Nile is at the same time in high flood, and it is the pouring of their united volumes into the White Nile, about the middle of June, that produces the inundation in Egypt.

The extent of the rise during a good "Nile," measured at the first cataract, is about forty feet; at Thebes it is reduced to thirty-six, at Cairo to twenty-five, and at the Damietta and Rosetta mouths to four feet. The inundations, regular though they are, vary somewhat in extent. It is of vital importance, however, to the Egyptian cultivator that this variation should be within comparatively narrow limits. Thus, if it does not attain a greater height than eighteen or twenty feet, it means

inevitable scarcity of food, while if it rises above twenty-seven feet it produces equally disastrous floods. The amount of rise in the Nile is the main element of uncertainty in the calculation of harvest prospects in Egypt. It is to the Egyptian peasant what weather is to the British farmer, and the Nilometer is as anxiously studied in the Nile valley as is the barometer at home. The official Nilometer is a pillar of marble, containing twenty-four cubits of twenty-one and one-third inches each, placed on an island near Cairo; and when the amount of rise on the Nile is stated, its height as marked on this graduated pillar is meant. Some idea of the amount of variability in the Nile flood may be gained from the published record of sixty-six consecutive inundations. Of these, eleven were very high, thirty were good, sixteen feeble, and nine insufficient. The inundation, however, has been known to fail altogether; for, not taking into account the seven years of famine in the time of Joseph, which probably refer to a time of scanty Niles, a similar period of seven years of total failure, and of consequent famine, occurred some centuries ago.

Nilometers have been in use from very early times, their object being to measure the amount of taxation to be levied on the country. So exactly could the ability of the Egyptians to pay taxes be gauged by this standard, that by an ancient

law no land tax could be exacted unless the Nile rose to the height of sixteen cubits. With the official Nilometer in their own hands, Egyptian Governments have not scrupled, however, to proclaim what is called the "completion of the Nile" before the waters had attained the proper taxable height.

The inundation usually attains the requisite dimensions between the 6th and 16th of August, but for fully a month previously the rise of the river is proclaimed daily in the streets of Cairo. On the "completion of the Nile," the dam at the mouth of the canal at Cairo is cut, and the beneficent work of irrigation begins. It is an erroneous idea to suppose that the Nile bursts its banks and pours in an unregulated flood over the land. The banks of the Nile are much higher than the country around, and during ordinary inundations they appear as long ridges above the surrounding water. The fertilizing stream is admitted to the fields by means of canals and cuttings, which form a complete network over the entire arable land; and the inundation continues longer than it would otherwise do, owing to the closing of the mouths of those canals when the Nile begins to fall, which thus prevents the water escaping by its natural channel to the sea. The Egyptians have also been careful to plant their towns and villages on elevations above the level of ordinary Niles, so that

during flood-time they rise like islands out of the water.

It is not moisture alone, however, which is thus brought to the Egyptian fields; the rich alluvial soil is annually increased by a layer of black mud and slime deposited from the turbid waters of the Nile. The layer is exceedingly thin, it having been calculated that during a century the deposit does not attain a thickness of more than four inches. Slowly but surely the soil of Egypt is thus being elevated; and as the height of the river-bed keeps pace with this growth, the result is that the inundation is annually spreading over a wider area, and the fertile soil is slowly encroaching on the desert. Thus it happens that statues and temples which it is known were never reached by the Nile waters three thousand years ago, now have their bases buried beneath several feet of alluvial soil. There is not, however, great room for extension, as the Nile valley, enclosed between two ranges of hills, has a breadth of only fourteen to thirty-two miles, while the breadth of arable land at present is about ten miles.

The volume of water in the river, which nowhere exceeds three-quarters of a mile in breadth, is enormous during the period of the inundation, seven hundred and fifty million cubic metres of water being, it is calculated, poured daily during that season into the Mediterranean. Much of the soil

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carried down on its turbid waters is thus taken out to sea, and it might therefore be supposed that the land would be rapidly gaining on the Mediterranean. Such, however, is not the case, the Delta having grown but little during the last two thousand years. However rapid its growth in former ages may have been, its progress is now checked by the action of a powerful current which, sweeping along the north coast of Africa, carries the Nile mud eastward with it.

The Nile deposit attains a great thickness in the Delta, and calculations have been made of its age, and of the antiquity of man in that region, founded upon the amount of its annual growth at the present day. Mr. Horner, investigating the latter point, obtained a piece of pottery from a depth of thirty-nine feet of Nile mud, and calculating that the deposit is increased at the rate of three and a half inches per century, the date of the pottery, and consequently of man's presence in the Nile valley, would thus reach back thirteen thousand five hundred years.

It is interesting at the present time, when so many British troops are in Egypt, to know that the quality of the Nile water has always been highly praised for its sweetness and wholesomeness. It has been placed among waters in the position of champagne among wines; and during a recent visit of a ruler of Egypt to this country, he brought a

supply of Nile water in jars for personal use during his absence. The peculiar flavour which makes Egyptians so fond of their river water is especially marked during the inundation, and can be got rid of entirely by filtration.

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THE END.